EXO:
Enriched Xenon Observatory

Search for Neutrinoless Double Beta Decay

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UTK Particle Physics/Cosmology Seminar
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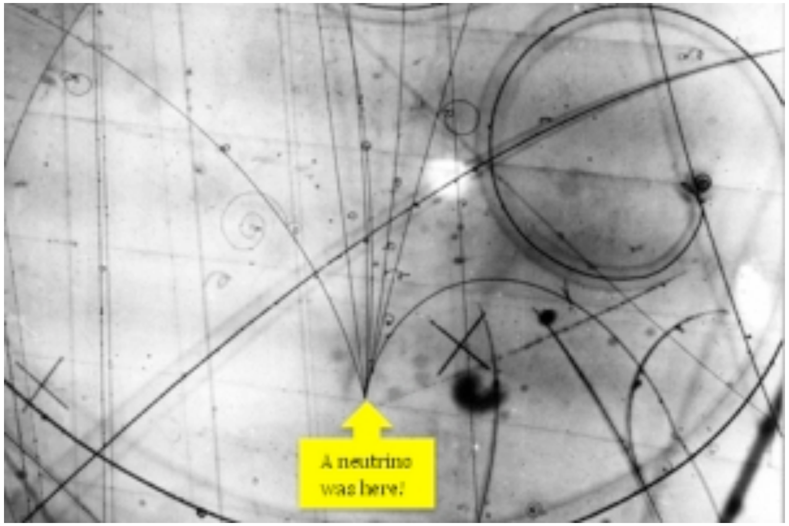
Neutrino History

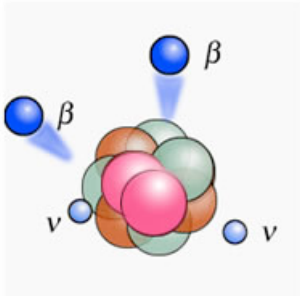
- 1931: Proposed by Wolfgang Pauli to explain beta decay conservations (he called them Neutrons, before the neutron was discovered)
- 1934: Re-named by Fermi and presumed in his theory of beta decay
- 1937: Ettore Majorana shows neutrino can be its own antiparticle
- 1956: Discovered by Cowan-Reines (electron neutrino)
- Other flavors proposed/discovered (muon/tau). Deficiency of solar neutrinos observed.
- 1998: First evidence of neutrino mass (Super-Kamiokande).



http://science.mit.edu/sites/default/files/styles/faculty_profile/public/neutrino2.jpg?itok=duAiWd6k

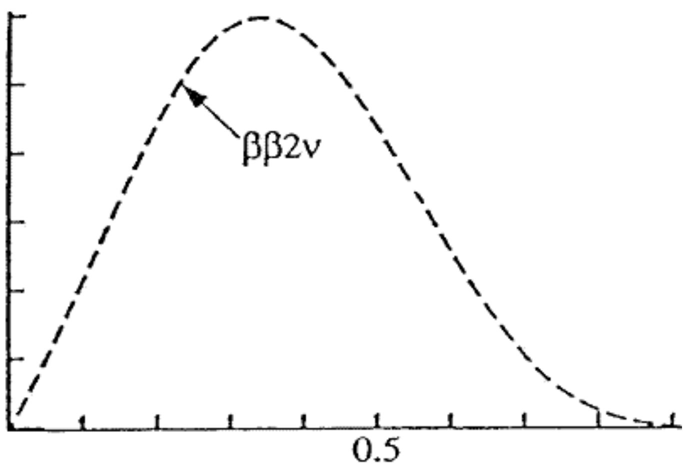
Neutrinos: where to next?

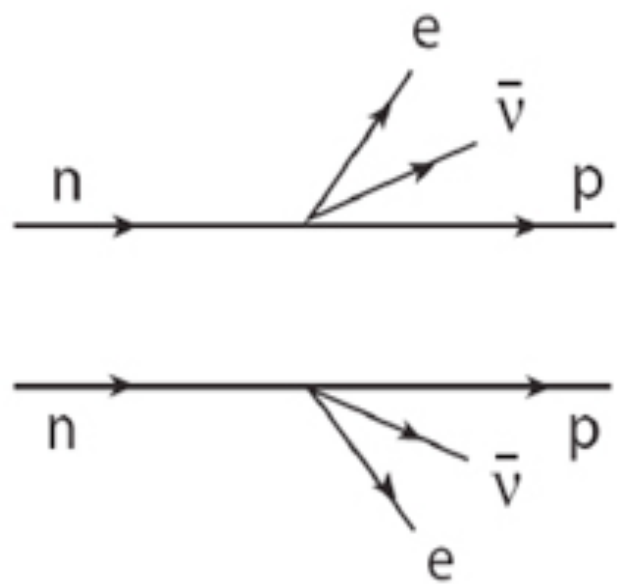
- What's left to discover?
  - Mass scale and mass hierarchy
  - Could show CP violation and leptogenesis
  - Are neutrinos **Majorana** or **Dirac** particles?
    - Answer would influence expansions of the Standard Model (GUTs and SUSYs)
  - Are there other neutrino types? Sterile neutrinos?
- Neutrino properties are important cosmologically, for expansions of elementary particle physics, and for astronomy



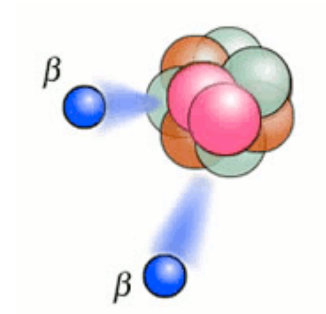
Double Beta Decay: 2υββ

- Occurs in even-even nuclei when normal beta decay energetically forbidden
- Two neutrons change into two protons, two electrons, and two electron antineutrinos

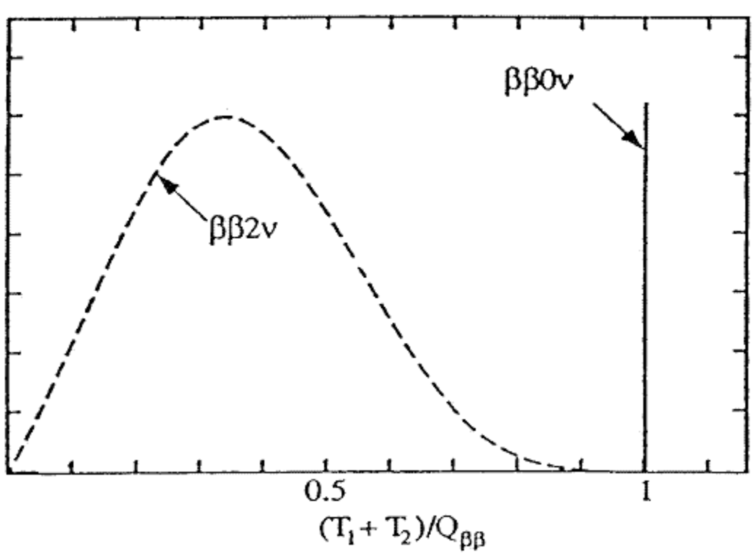


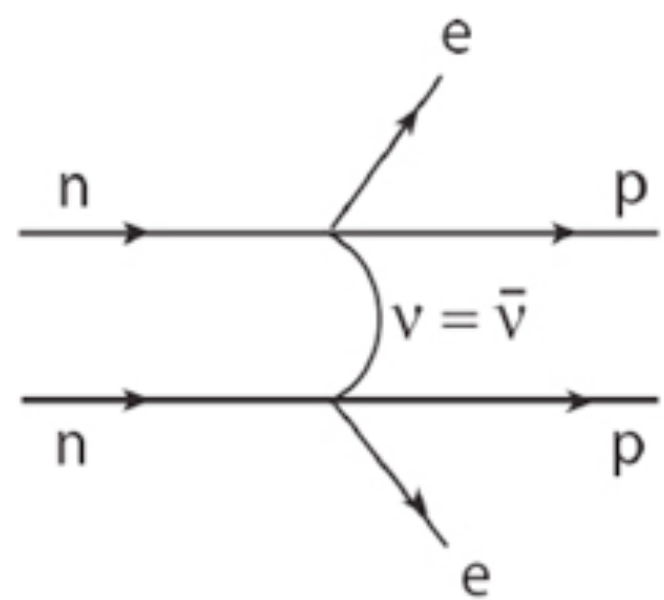


Neutrinoless Double Beta Decay: 0υββ



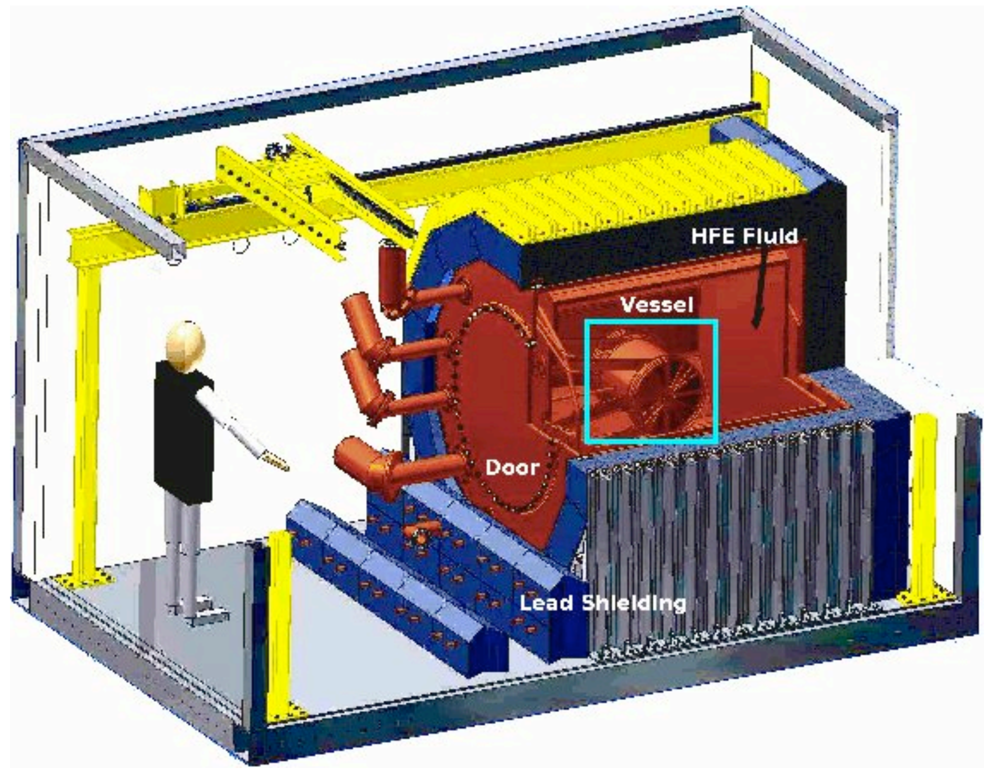
- Two neutrinos change into protons, two β-particles (electrons) are ejected
- Electrons carry away energy as from normal beta decay plus neutrino energy
- Existence would prove





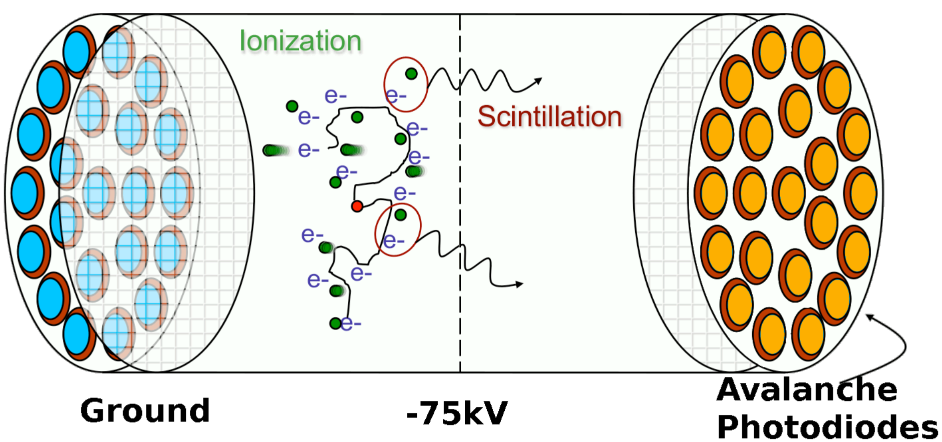
EXO-200

- 200 KG Prototype
- Decay Material: Xenon-136
- Scintillator Material: also Xenon
- Detector types: Time Projection Chamber (TPC) and and Large Area Avalanche Photodiodes (LAAPD)
- Located at Waste Isolation Pilot Plant in New Mexico



EXO-200: Primary Goal

- **Measure electron energies**
  - TPC Measures Momentum of drift electrons (formed by ionization when β electrons are produced)
  - LAAPDs provides time of event combined with XY grid location from TPC to mark event location
- Compare these energies to the **Q value of Double Beta Decay**
- Same energy always observed => No 0υββ
- Spike at Q value of 2υββ => 0υββ

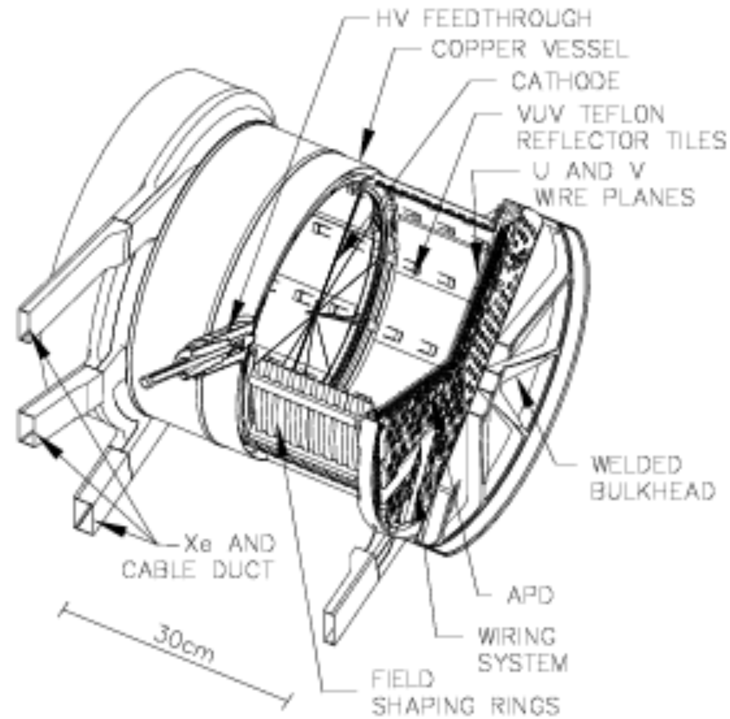


Why Xenon?

- Candidate for 2υββ – first verified by EXO (2011), and therefore 0υββ
- Acts as a scintillation material (convenient!)
- Easy to enrich – can be enriched in conventional centrifuges (Xe-136 enriched to 80%, 19% Xe-134, with other negligible isotopes)
- High Q-value (2457. 83 ± 0. 37 keV) occurs above most gamma ranges

TPC

- Cylindrical copper cryostat filled with LXe
- Voltage of 376V/cm across length of cylinder
- 38 charge induction wires and 38 charge collection wires form 2D position grid
- Electron drift time from calibration around 3ms
- Cooled to 167K to maintain liquid Xe
- Xenon is recirculated



EXO Shielding

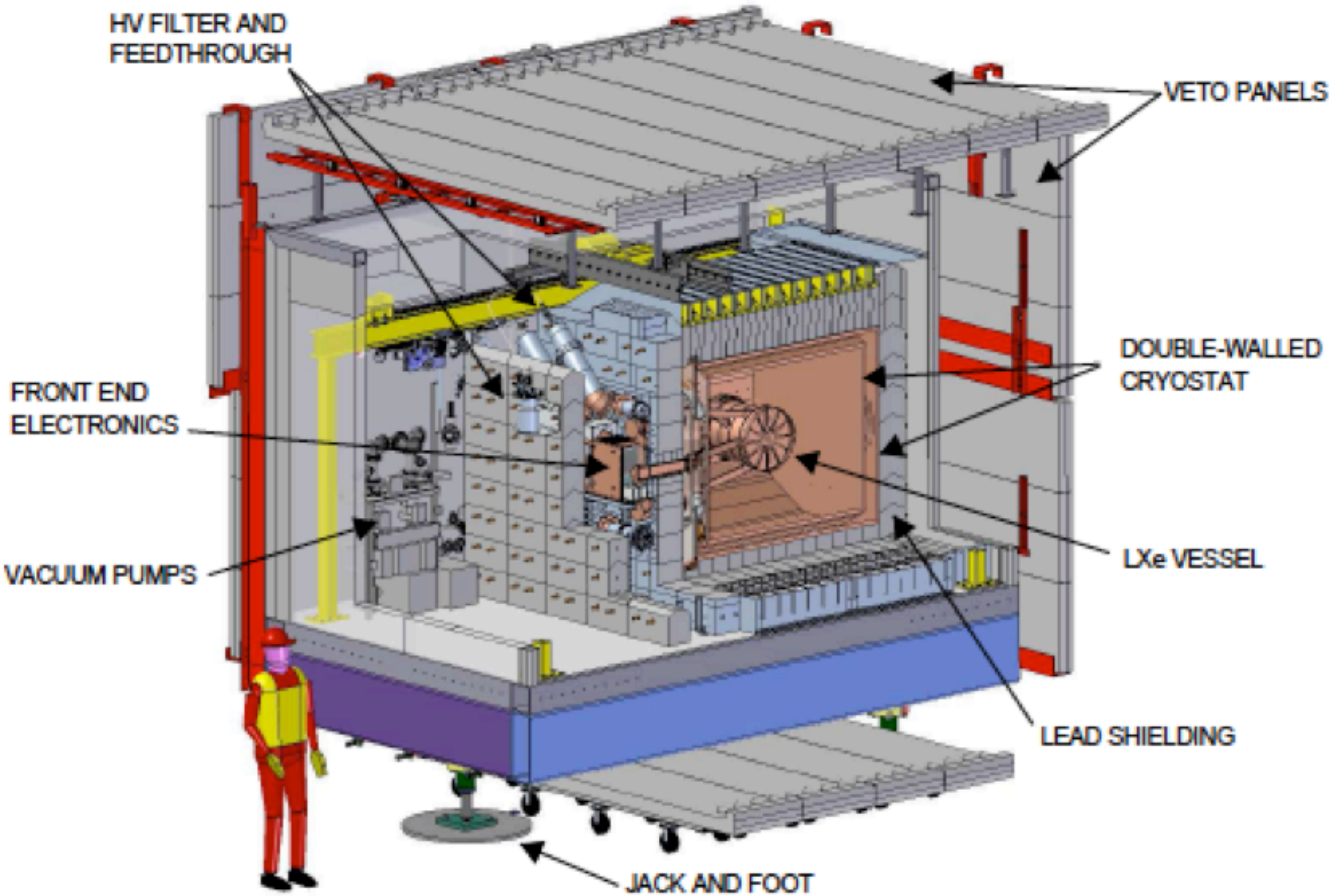


Figure 2. Cutaway view of the EXO-200 setup, with the primary subassemblies identified.

Shielding

- TPC Cryostat is contain in larger copper cryostat filled with HFE7000 Fluid
  - HFE Fluid acts as shielding as well as heat transfer medium
- Next layer: 25cm lead
- Then, plastic scintillator veto panels to actively remove counts during muon traverses
- At WIPP, equivalent of 1585m of water (actual depth 655m)

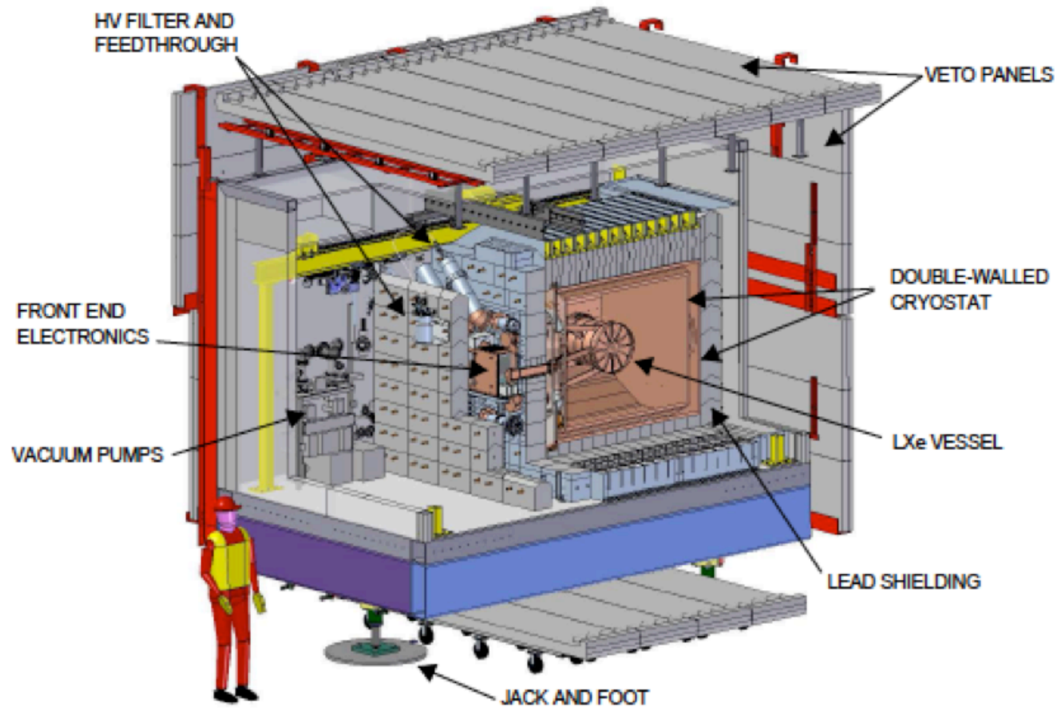
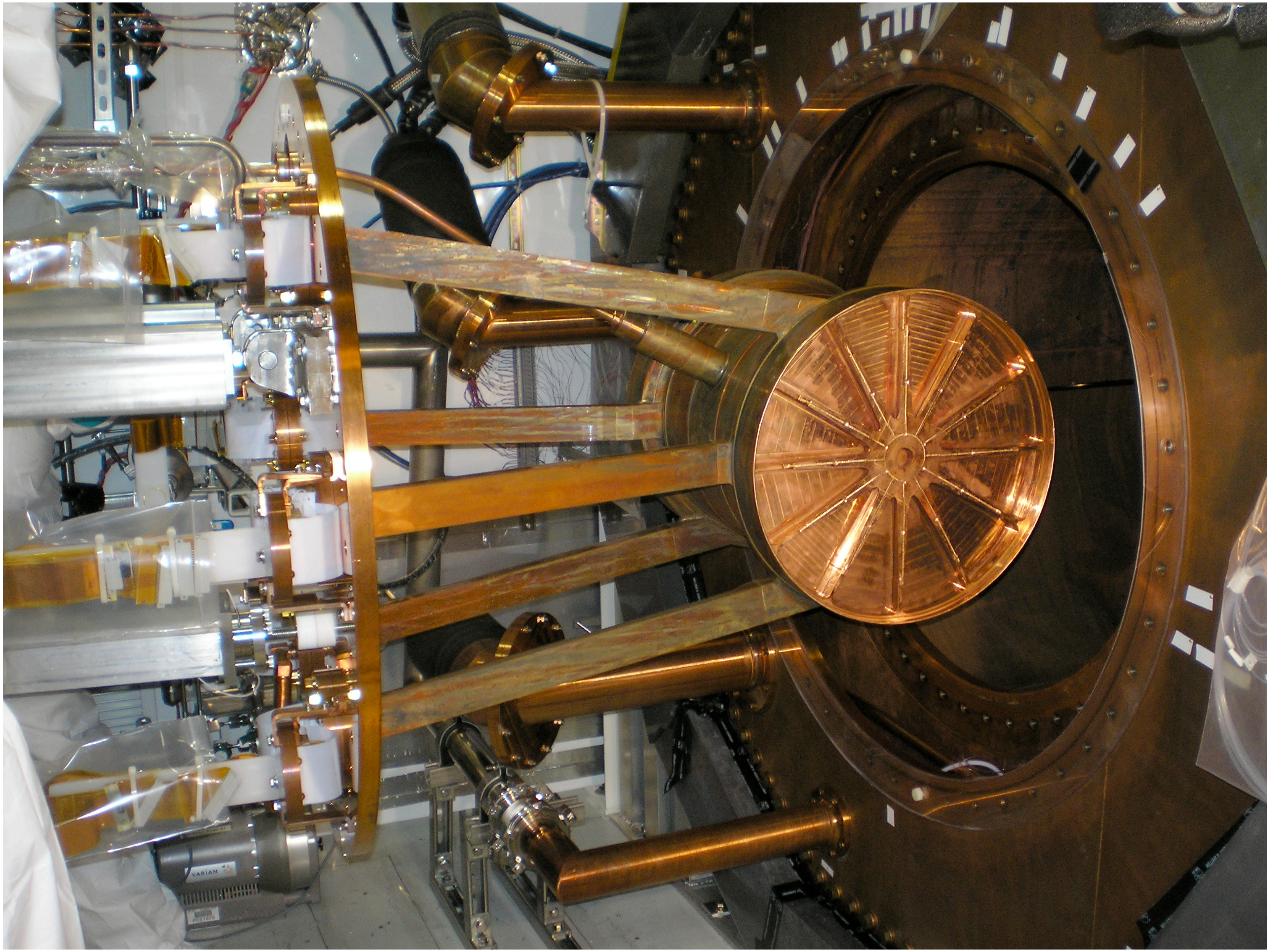
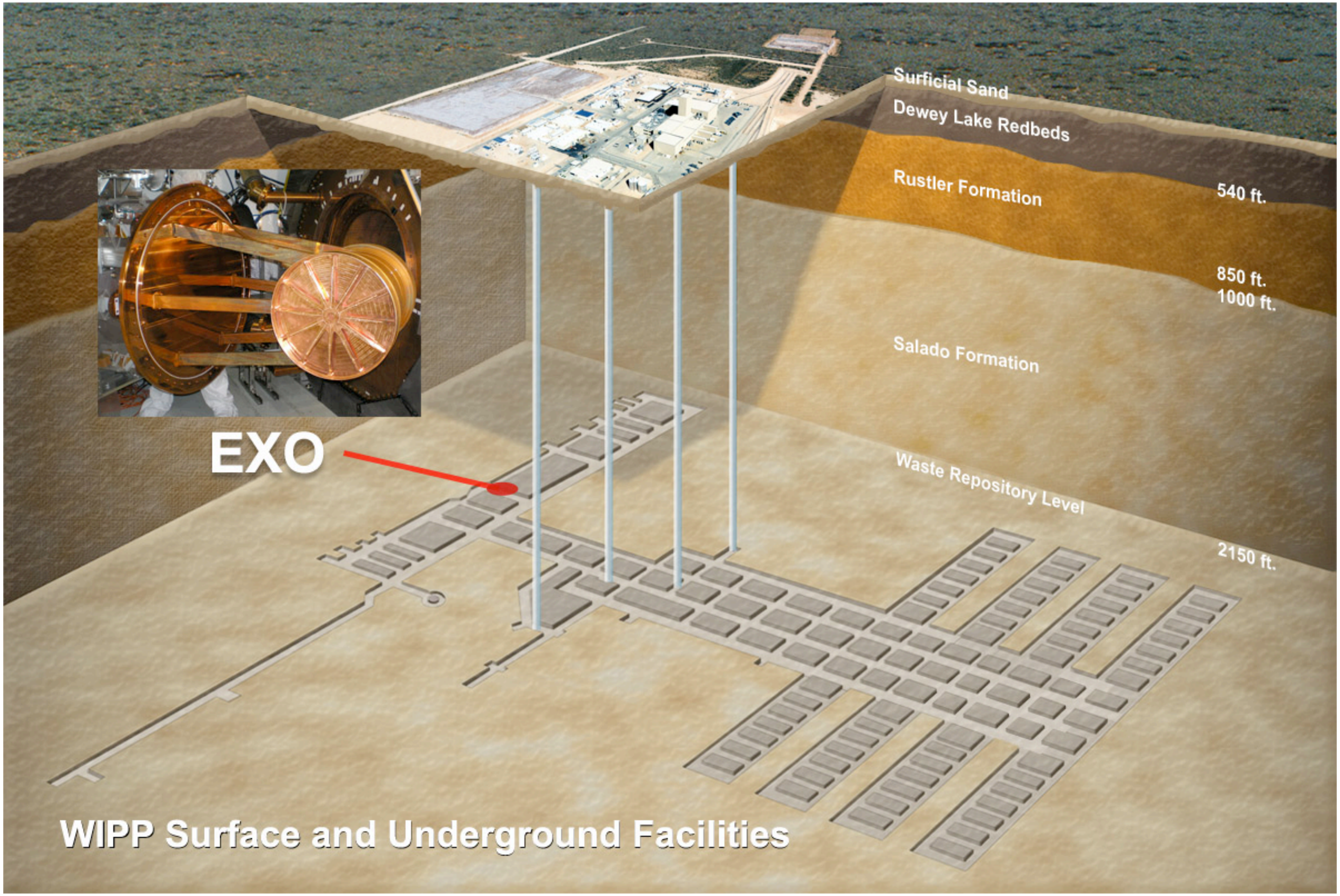


Figure 2. Cutaway view of the EXO-200 setup, with the primary subassemblies identified.

TPC Cryostat into shielding Cryostat



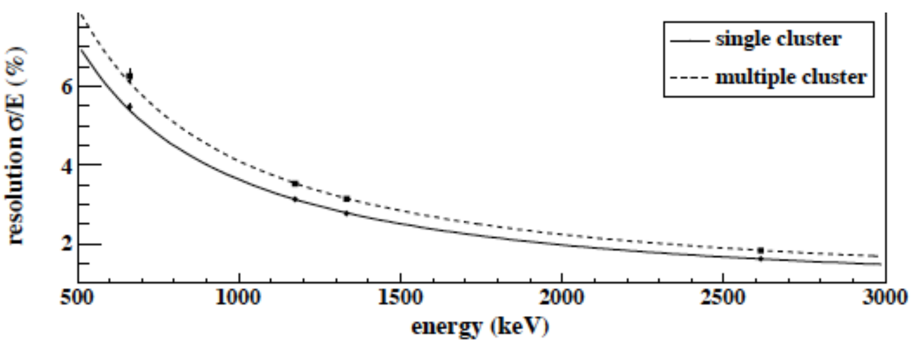
Waste Isolation Pilot Plant

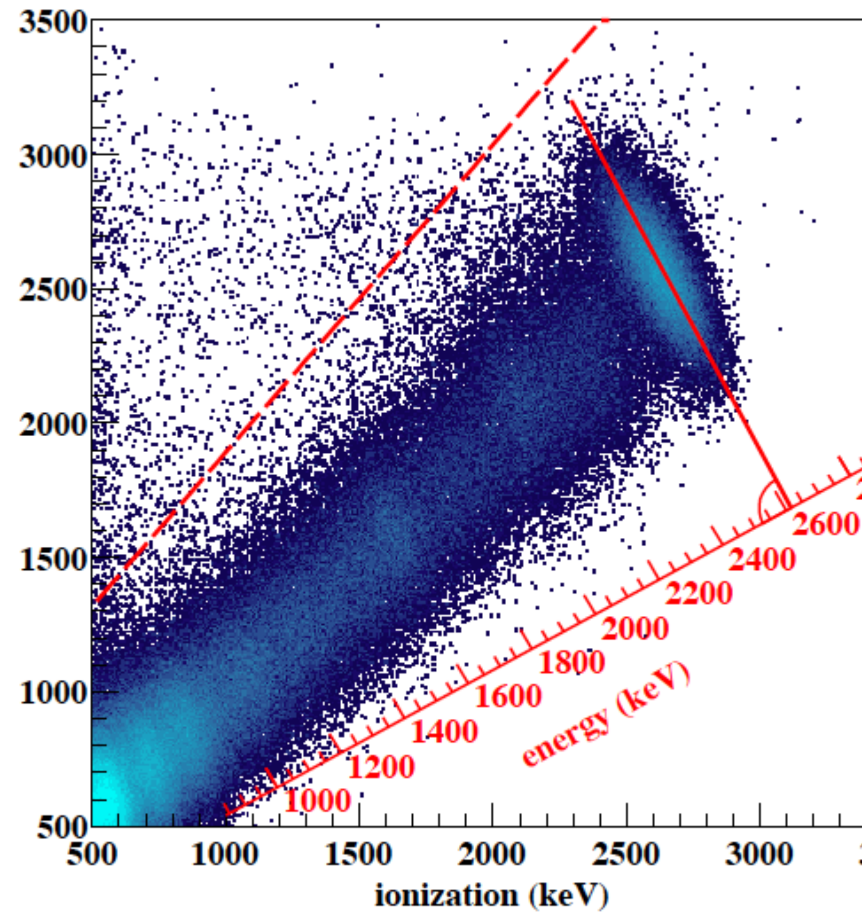


Resolution

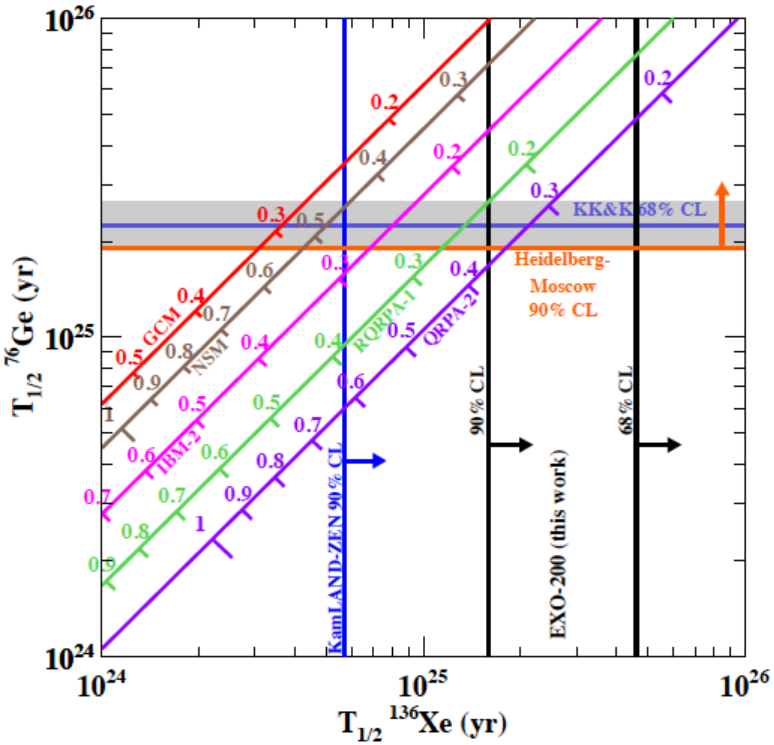
Right: Energy resolution is greatly improved by using a linear combination of ionization signal (horizontal; from TPC) and scintillation signal (vertical)

Below: observed resolution using Th, Co, and Cs calibration targets



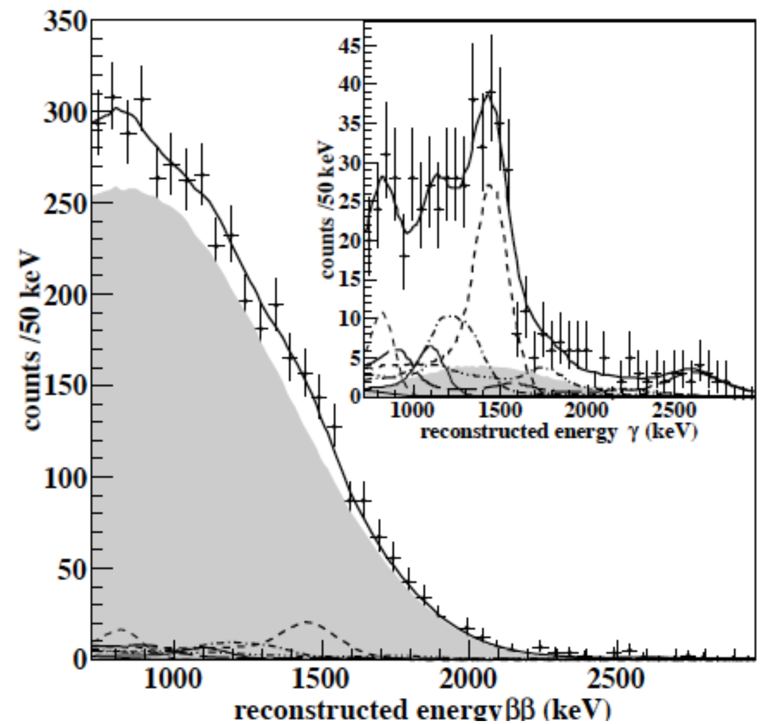


Measurements (so far)

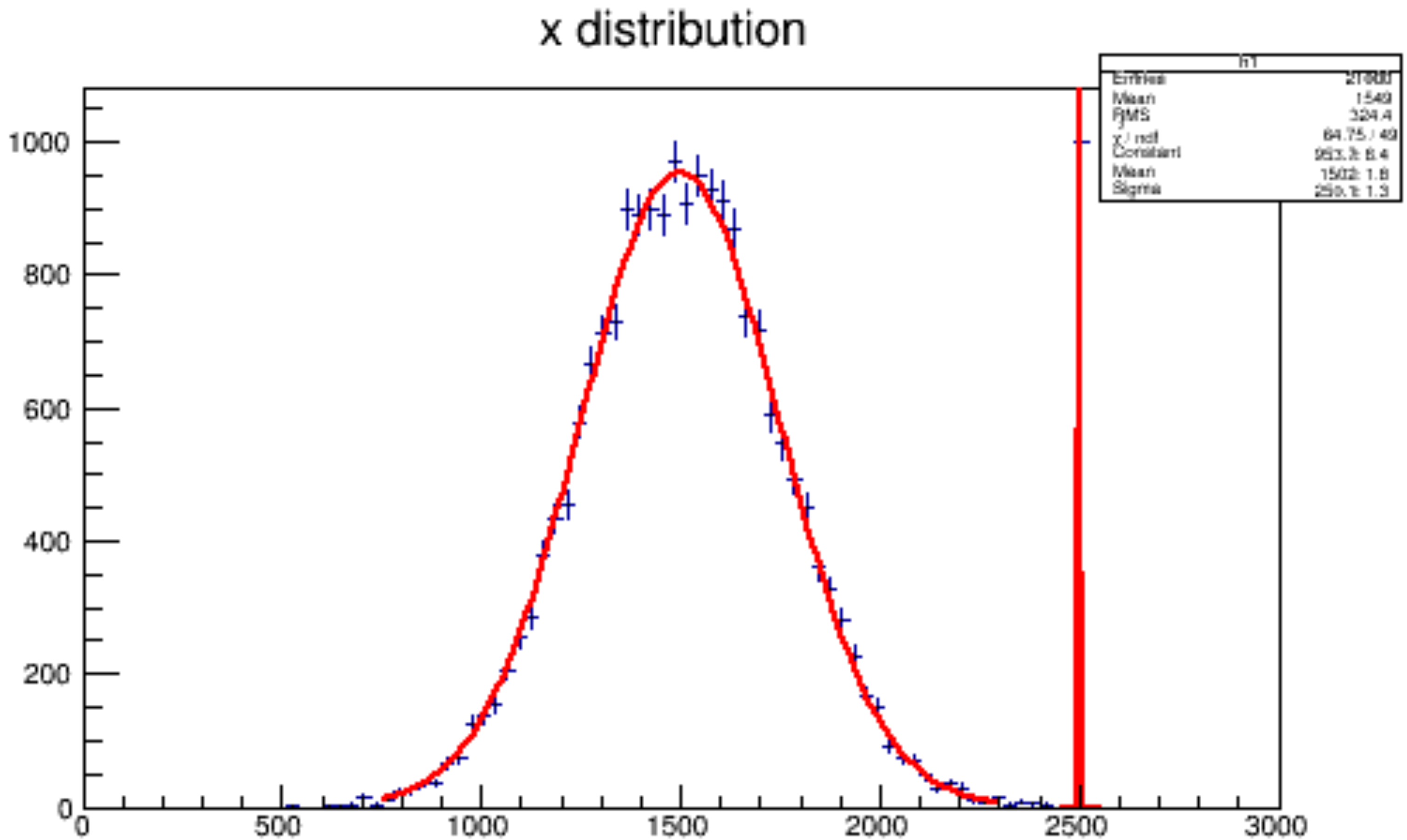


- First observation of 2υββ in ^{136}Xe (below) , with half life of 2υββ ~ 2.1*10^{21} years

Best estimate of 0υββ decay rate and mass upper limit: ~1.6*10^{25} corresponding to a mass limit of 140–380 meV



What we're looking for: 0υββ



(Don't look too closely: this is me trying to learn Root

nEXO

- Larger version proposed: increase to 5 ton Lxe enriched to 90% (up from 80%)
- Ambitious – requires refinements in most areas of EXO makeup
- Goal of fast tagging Barium ion product of Xe decay to further reduce background