The Turn-on of EXO-200

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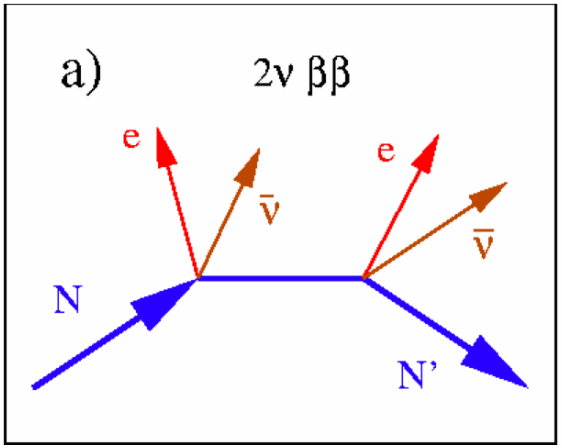
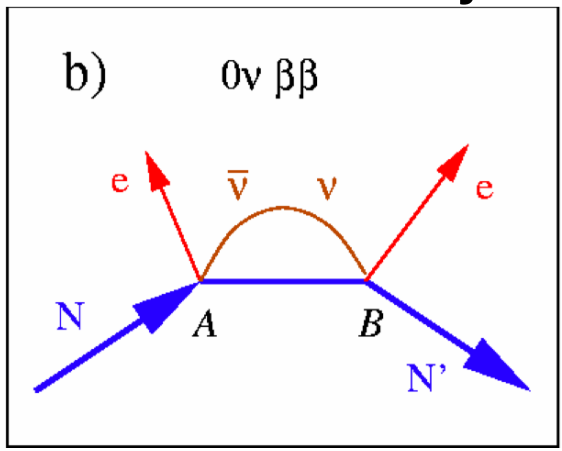
On behalf of the EXO Collaboration

APS April Meeting 2011

Enriched Xenon Observatory

- EXO (Enriched Xenon Observatory) is a series of experiments to look for the neutrinoless double beta decay of xenon 136





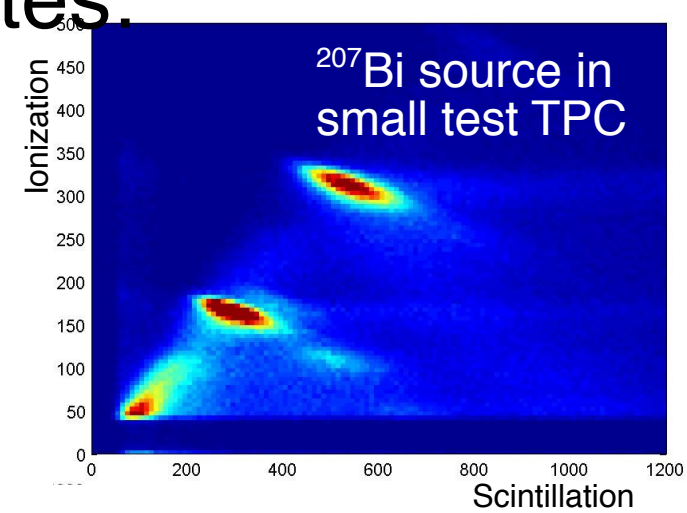
  - Only occurs if neutrino is a Majorana particle
  - Half life goes like $\left(T_{1/2}^{0\nu\beta\beta}\right)^{-1} \propto \langle m_\nu \rangle^2$ (and ν mass is small!)

$$\langle m_\nu \rangle = \sum_{i=1}^{3} |U_{e,i}|^2 m_i \epsilon_i$$

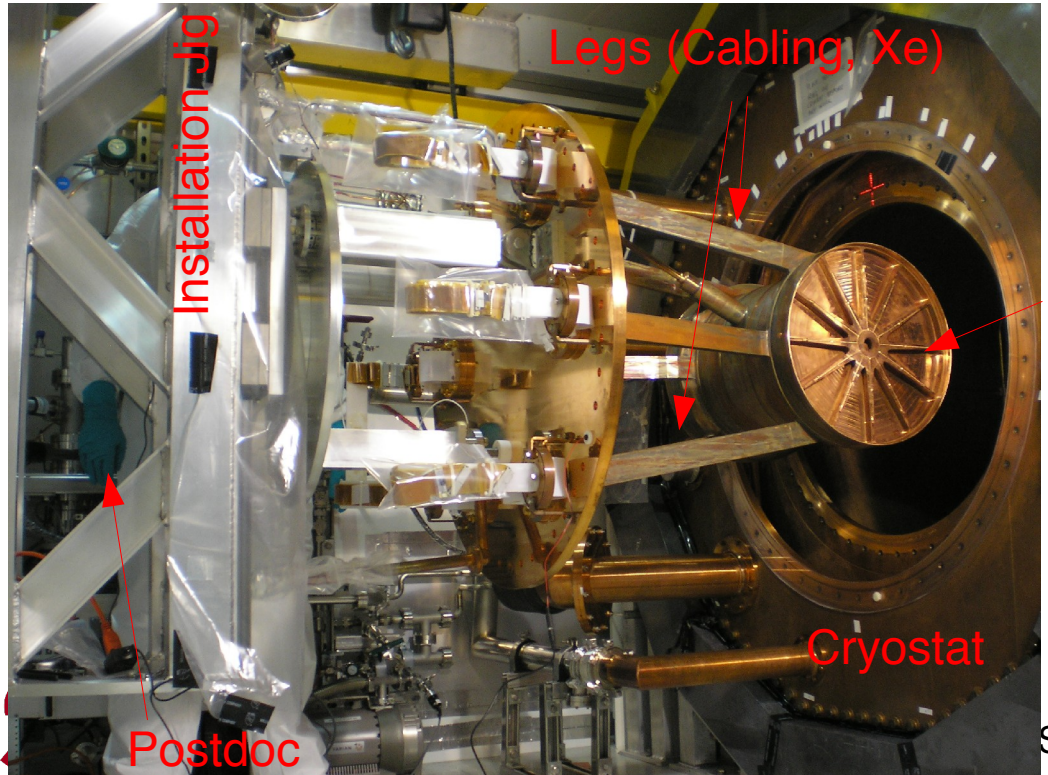
  - Violates lepton number conservation
- EXO-200 is a TPC utilizing 200 kg liquid xenon installed at the WIPP site (~1600 mwe) near Carlsbad, NM

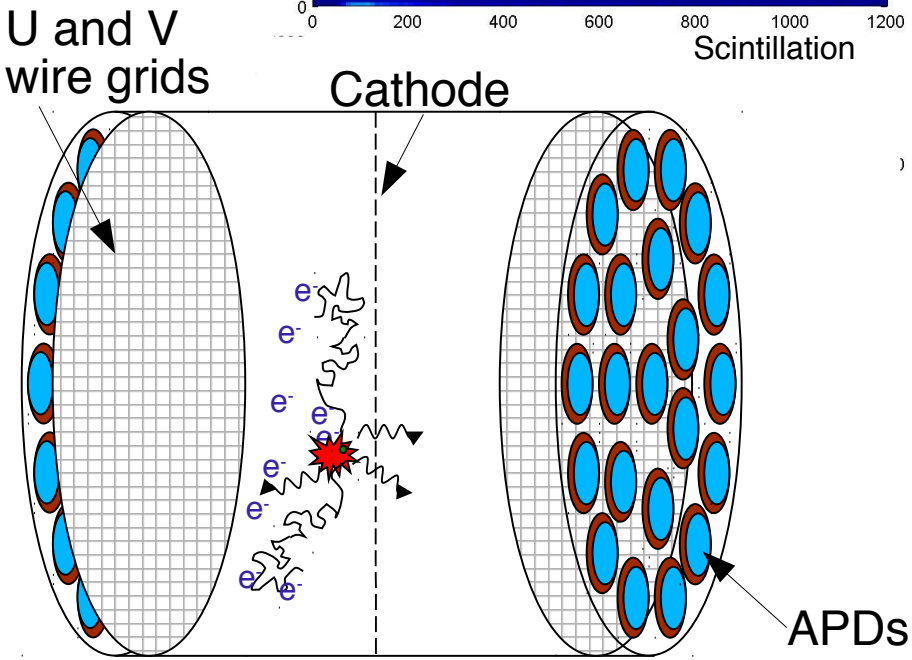
EXO-200 TPC

- Xenon serves as both source and detector
- Energy deposited in xenon creates:
  - Charge: drifted to wires
  - Light: collected by LAAPDs
  - (The two signals can be combined)



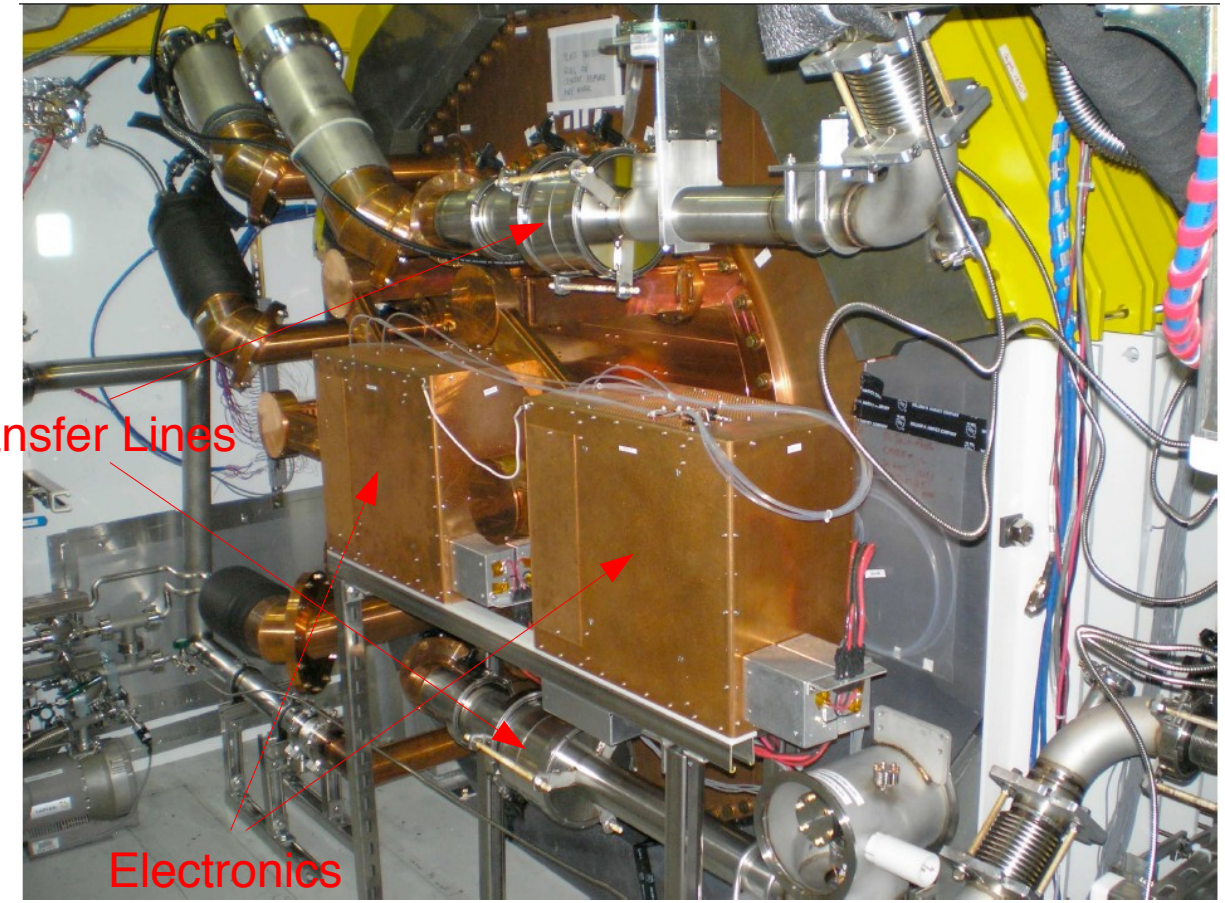
E.Conti et al., Phys. Rev. B: 68 054201 (2003)



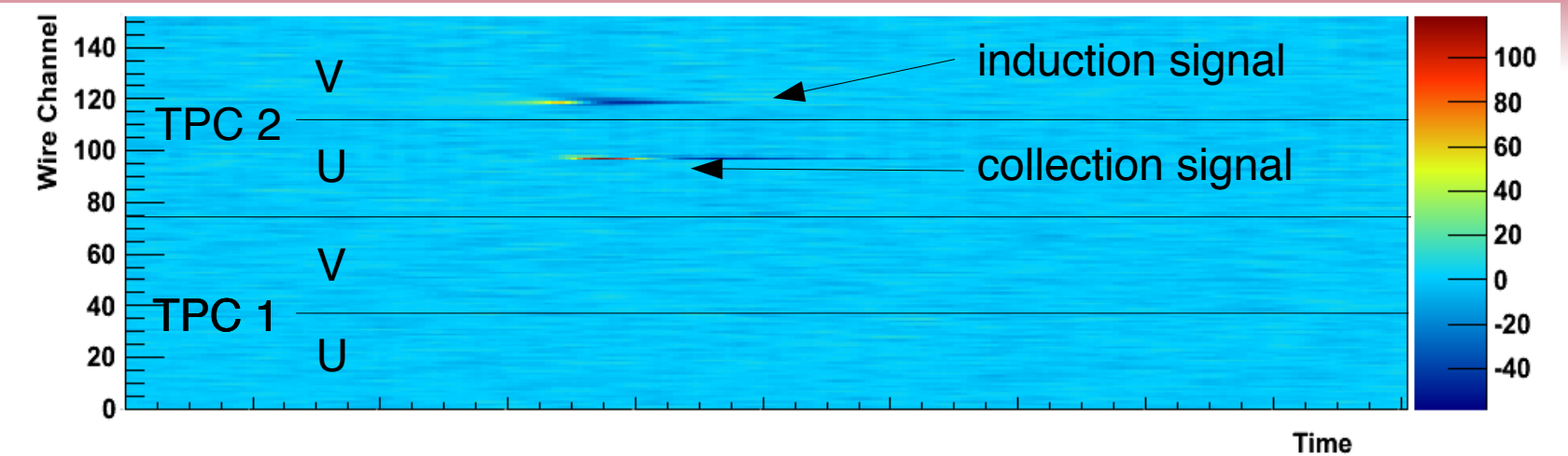


Engineering Run

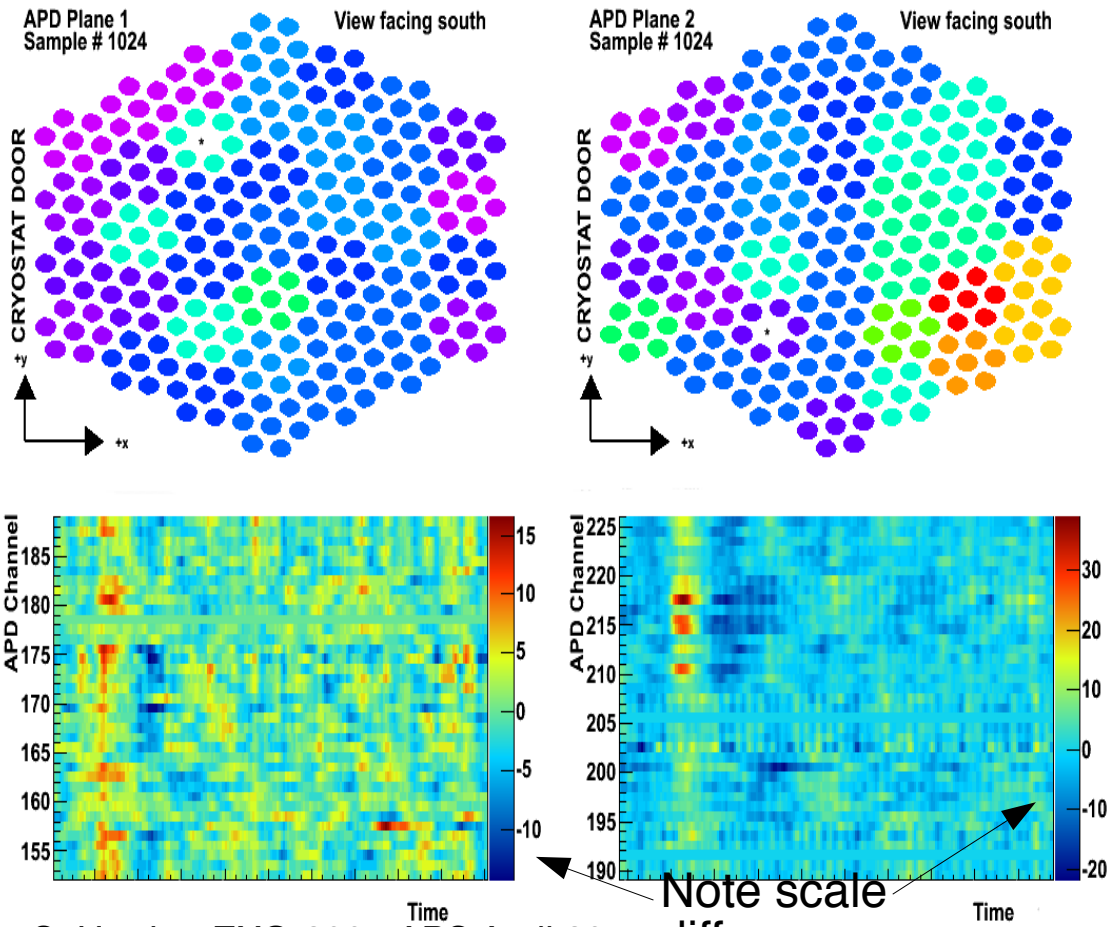
- Engineering Run ~Dec 2010
- Natural xenon
- TPC fully operational, but not in low background mode:
  - No front Pb wall
  - No Rn free enclosure
  - No Rn trap
  - Muon veto not running
- Test:
  - Electronics
  - Emergency Procedures
  - Stability
  - etc.



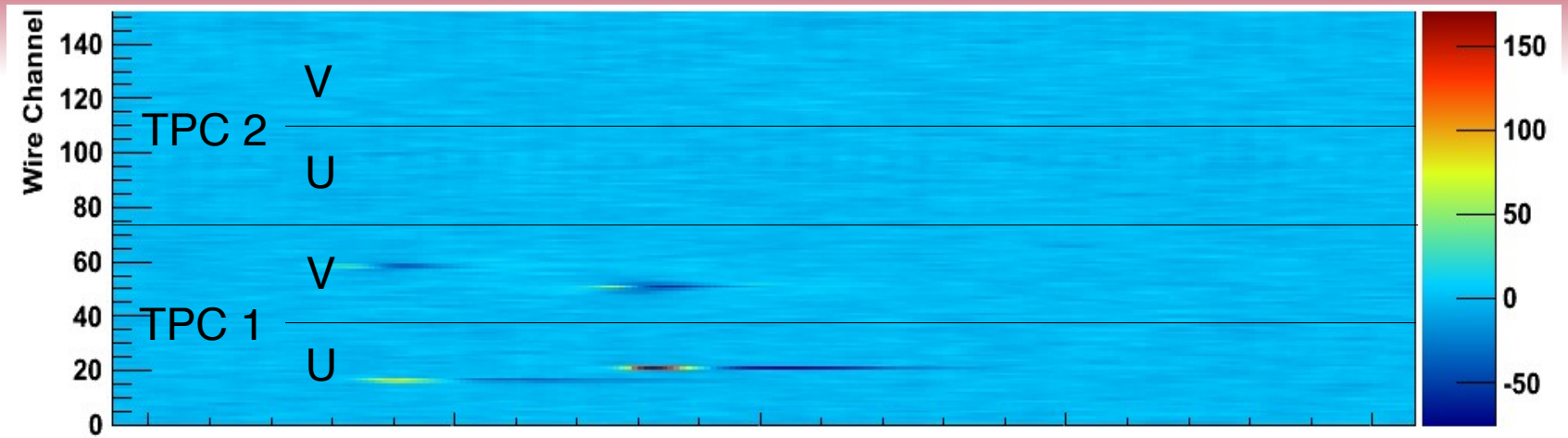
An Event in EXO-200



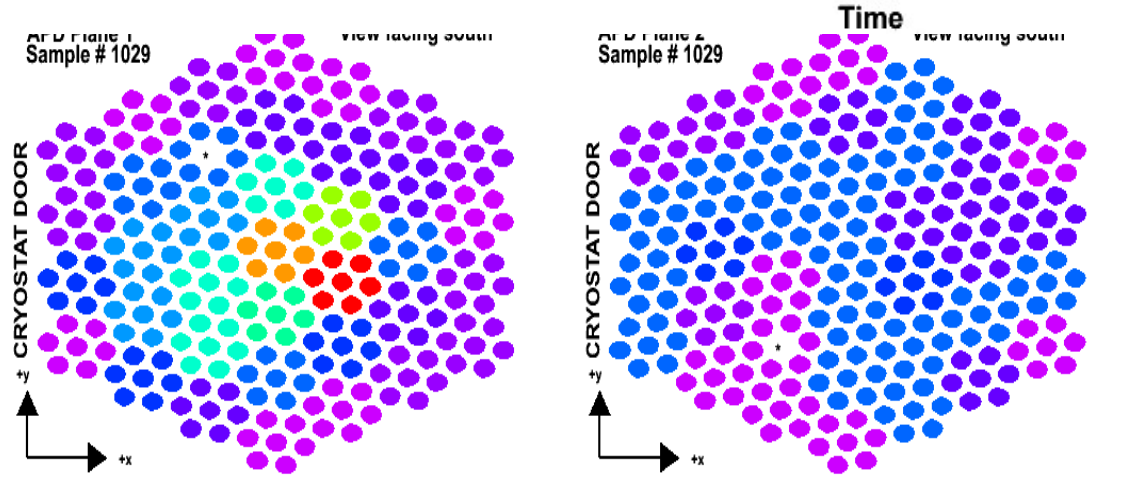
- Charge signal is picked up on crossed wires (shown above)
  - V wires (induction) see it before U wires (collection)
- Light signal is shown at right. This event occurs in TPC 2, and so most light is there, but some is collected in TPC 1
- Light signal precedes charge signal

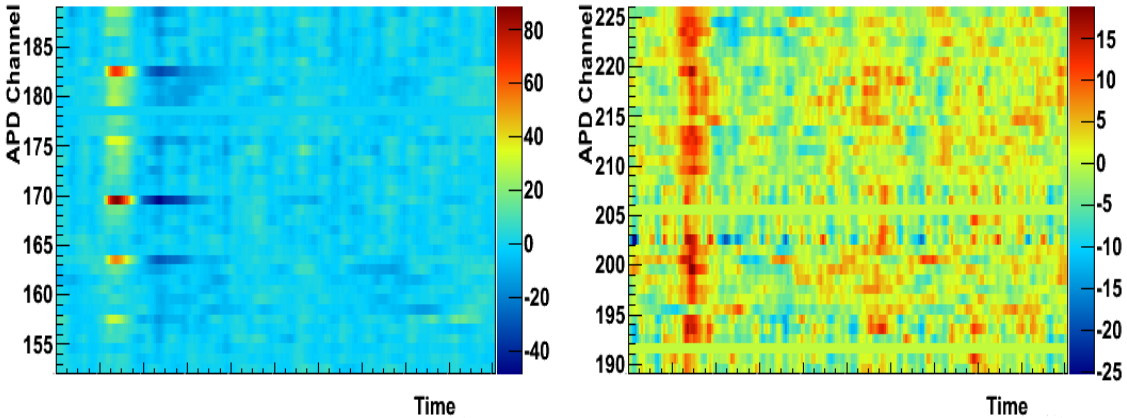


A 2-site Event in EXO-200



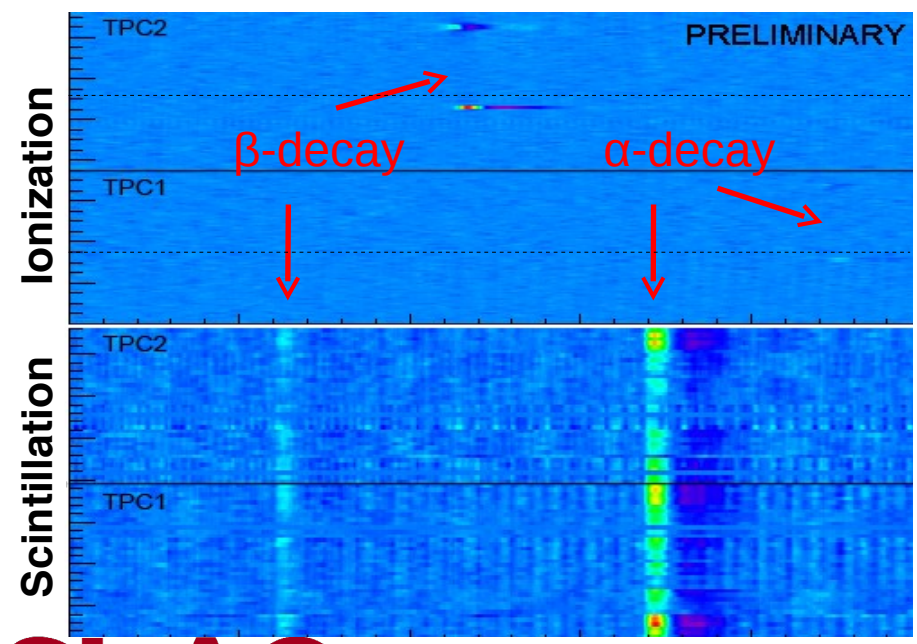
- Gamma rays can Compton scatter in the TPC, creating multiple site events
- All scintillation light arrives simultaneously, indicating multiple-site event and not coincident single-site events
- For this event, both sites were in TPC 1

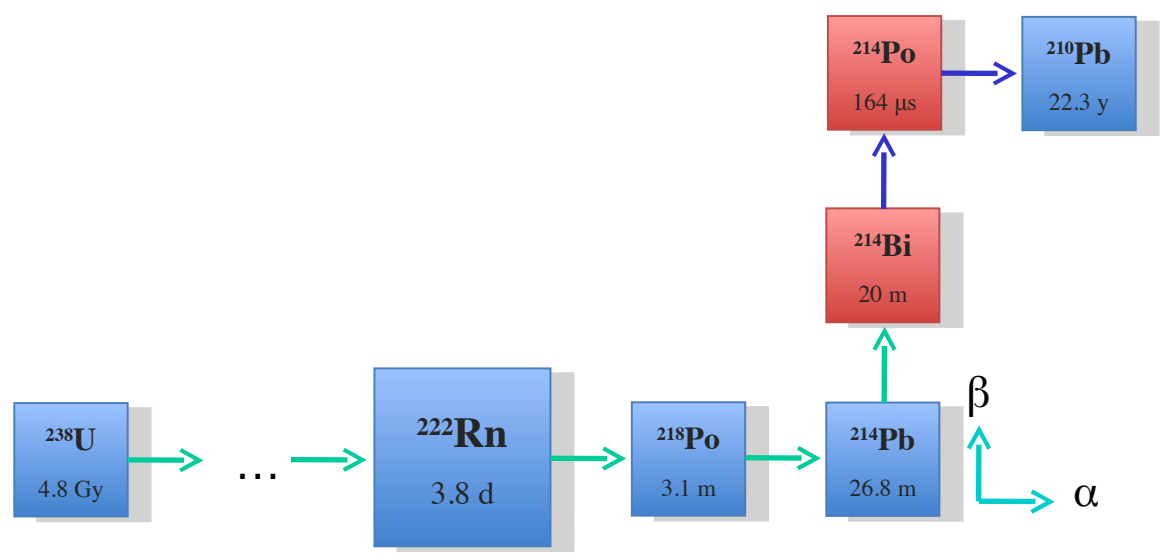




Particle ID and ^{214}Bi-^{214}Po Decays

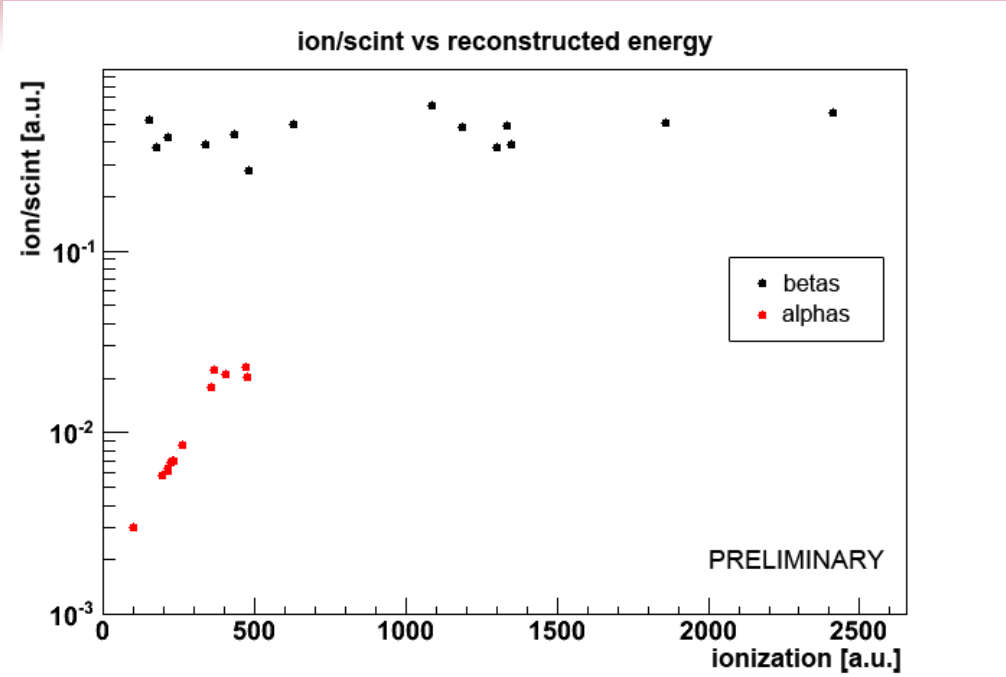
- Alpha particles have large dE/dX. The large energy deposition means more ions recombine, producing more scintillation light than betas do
- Beta decays produce more ionization signal than alphas
- ^{214}Bi β-decay is followed by a ^{214}Po α-decay, τ=237 μs. This has a topology that can be identified in the detector and likely occurs in a single trigger frame.

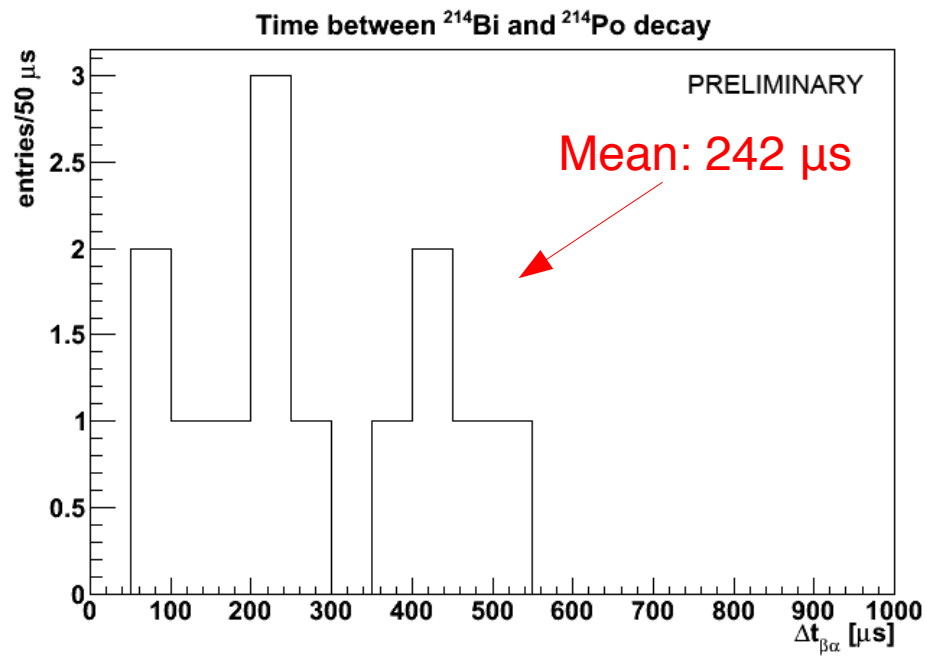




More ^{214}Bi-^{214}Po Decays

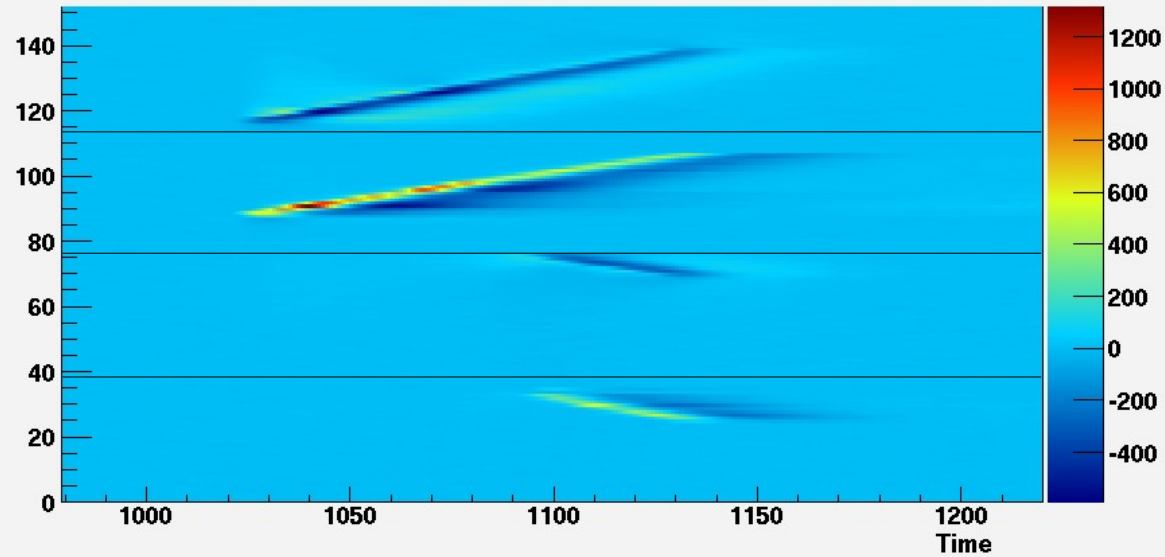
- Ionization/scintillation ratios allow clear discrimination between α and β events
- A simple check of engineering run data finds 15 Bi-Po events
  - Efficiency still under study, but seems rate is consistent with what is expected with no Rn trap on system
  - 6 near cathode, the remainder in bulk
  - Mean lifetime consistent with 237 μs

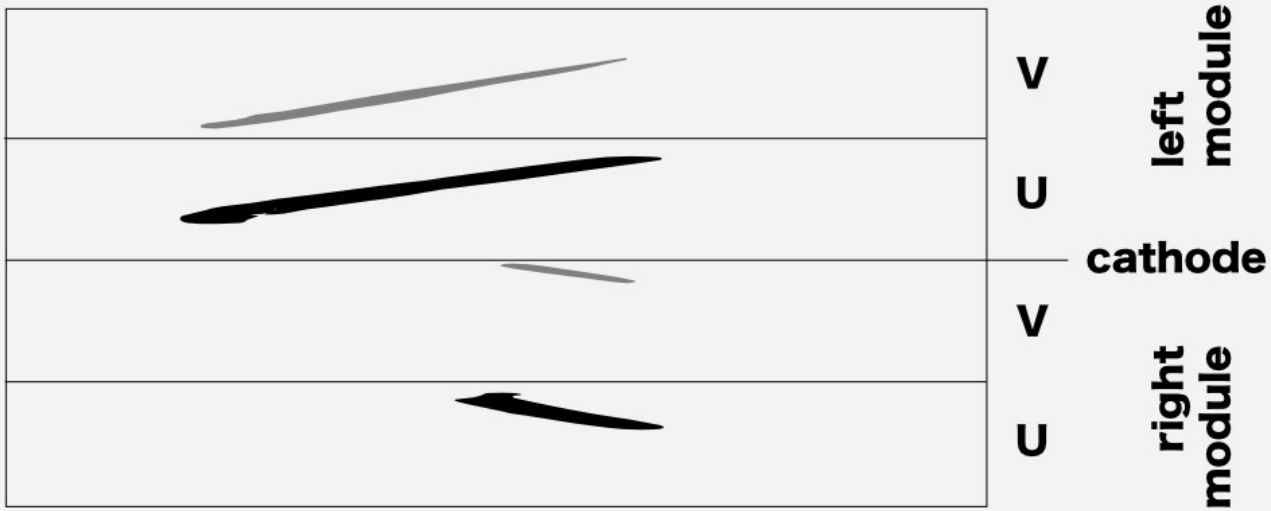




Muons in the TPC

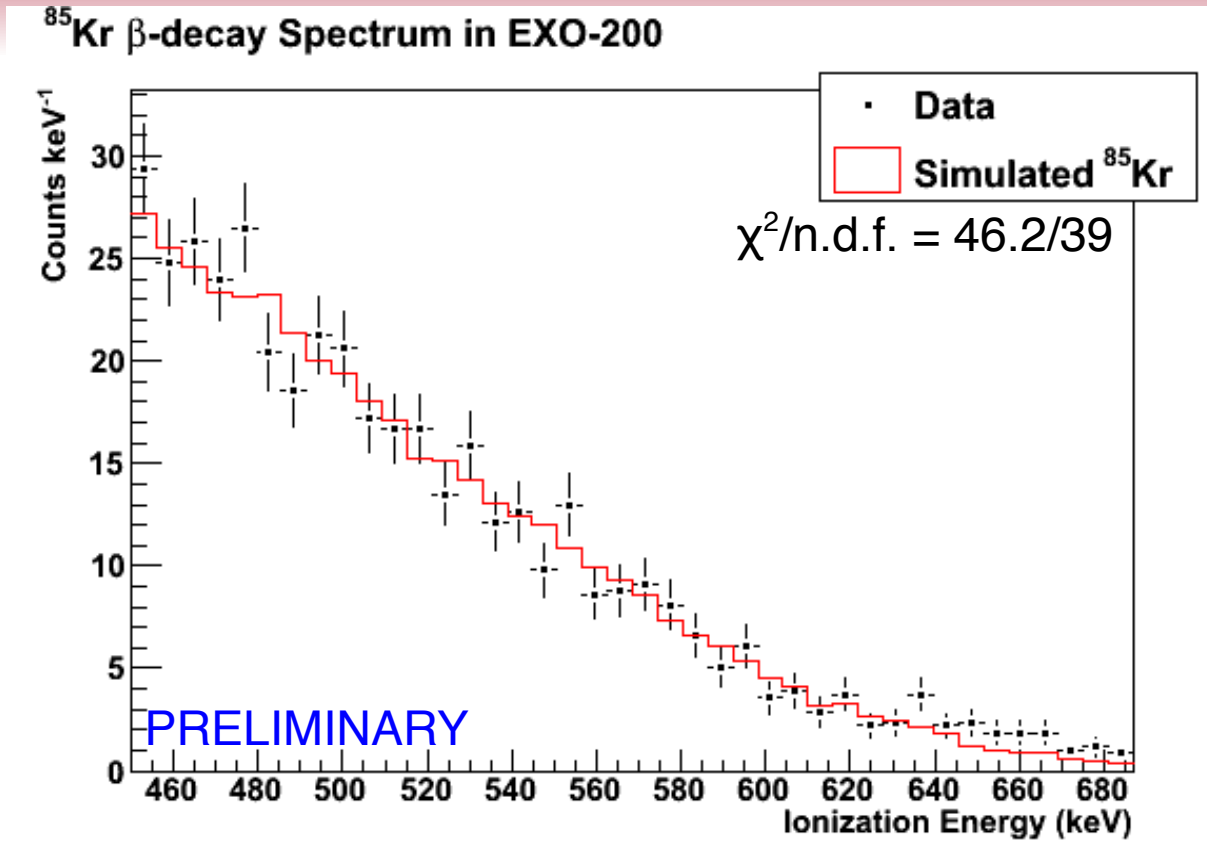
- Muons leave ionization trail in the xenon
- This muon traverses the cathode, leaving ionization in both TPC halves
- We can identify these trails and get a rate that agrees with expectations at our depth





^{85}Kr in the TPC

- The low energy spectrum is consistent with ^{85}Kr contamination in the natural xenon used for the engineering run
- Plot shows simulated spectrum scaled to match data in 450 – 687 keV region
  - 450 keV chosen to be well above trigger
  - Q = 687 keV

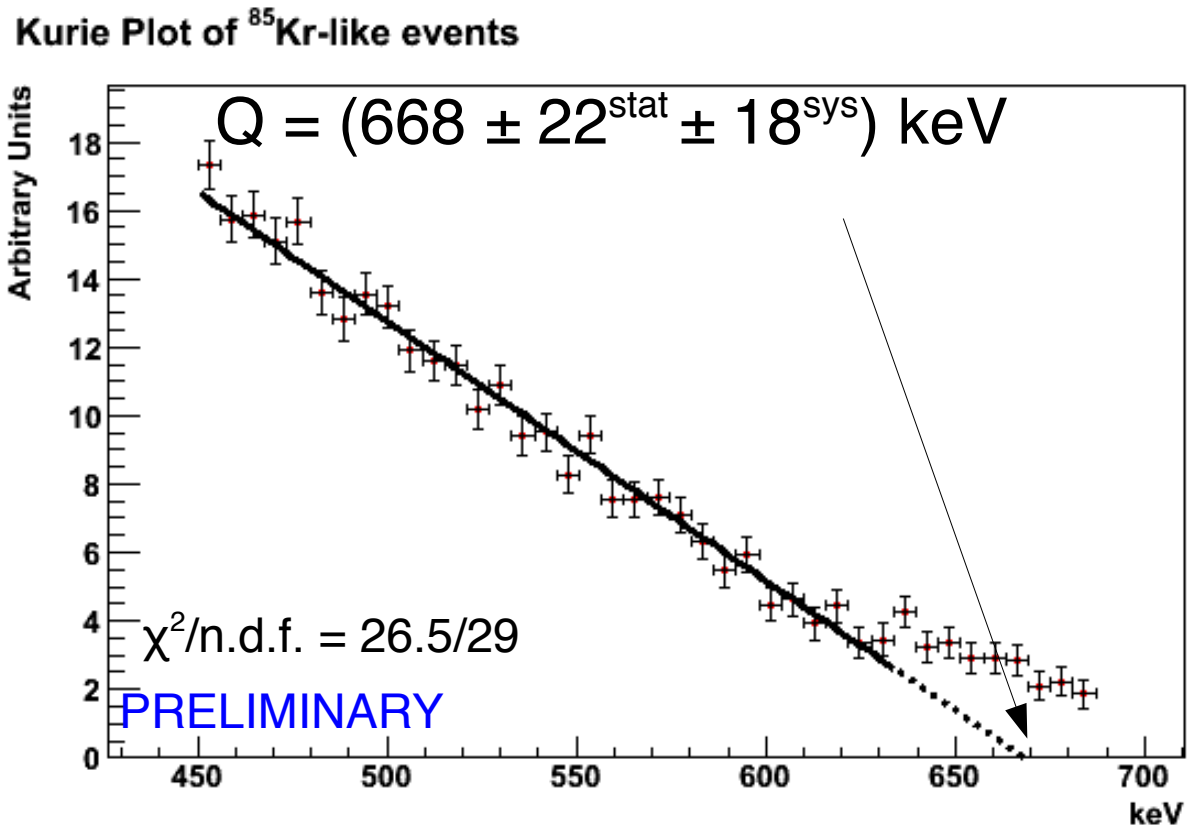


- Rate consistent with ~10^{-11} abundance of ^{85}Kr/Kr based on mass spectrometer† analysis of xenon

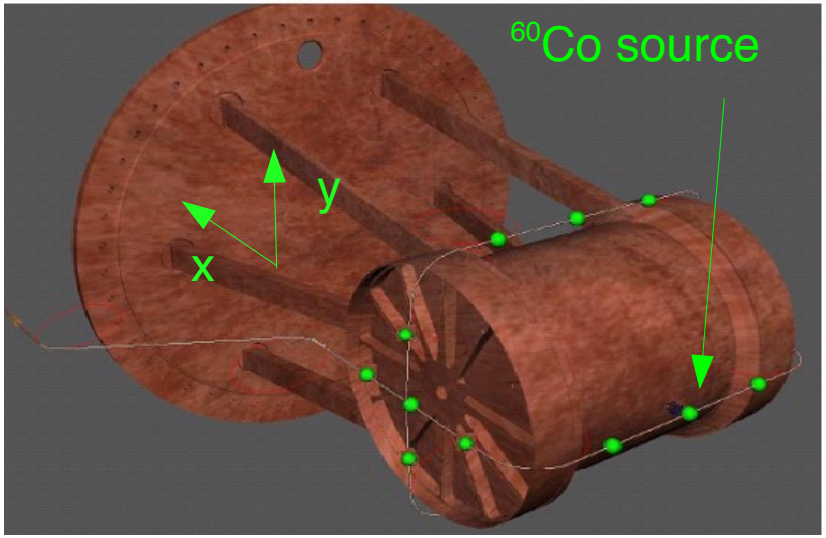
†A.Dobi et al., arXiv:1103.2714v1

Q value for ^{85}Kr

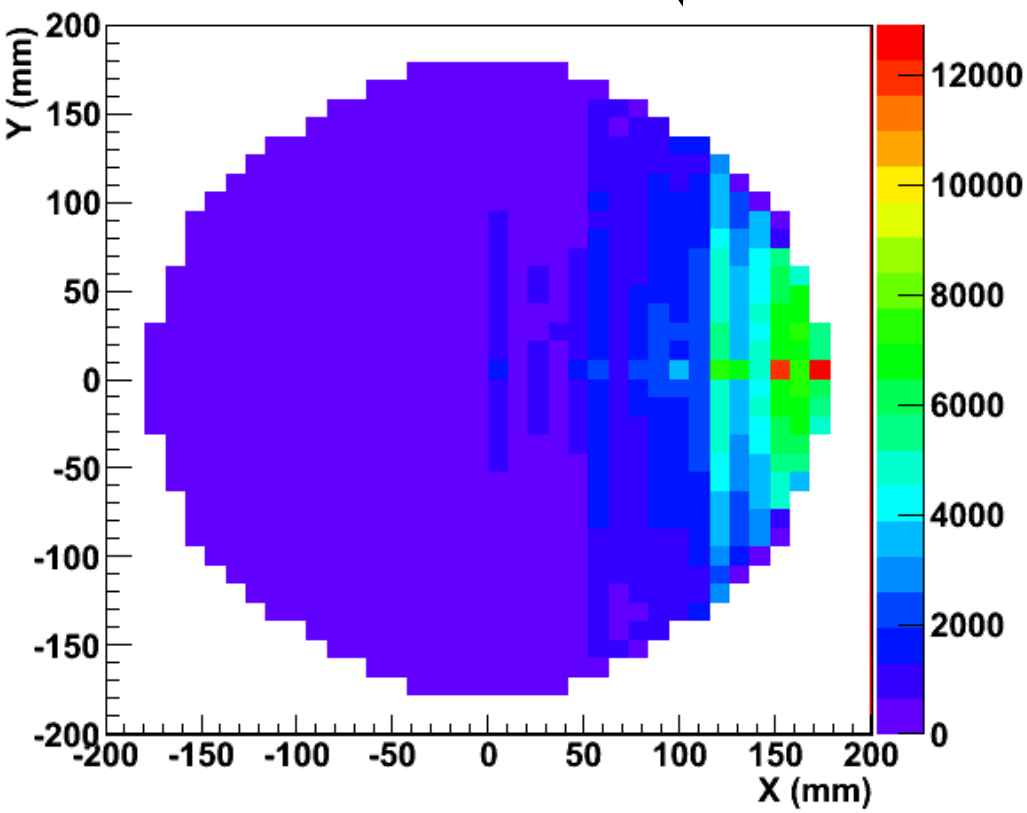
- At higher energies, other backgrounds start to contaminate spectrum
- Fit a line to Kurie plot between 450 and 635 keV to obtain Q value consistent with 687 keV
  - Energy scale verified with ^{60}Co source data



^{60}Co Source



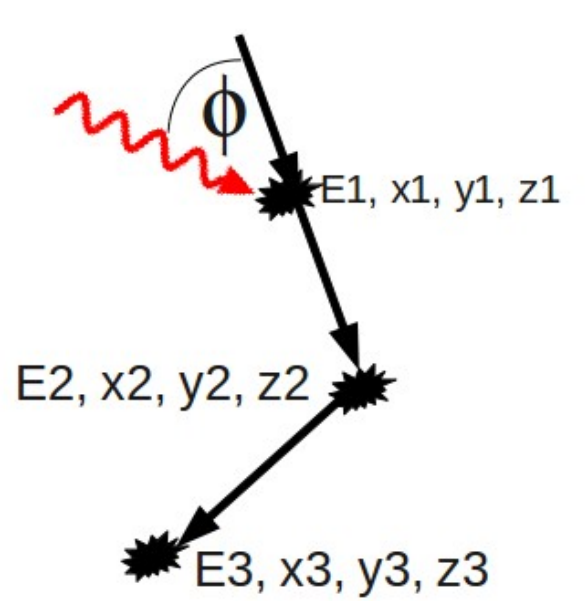
^{60}Co at the cathode produces this distribution of events in x-y plane



For calibration, various sources can be placed in positions near the TPC

- e.g. ^{60}Co just outside the cathode along +x axis

Compton telescope of ^{60}Co

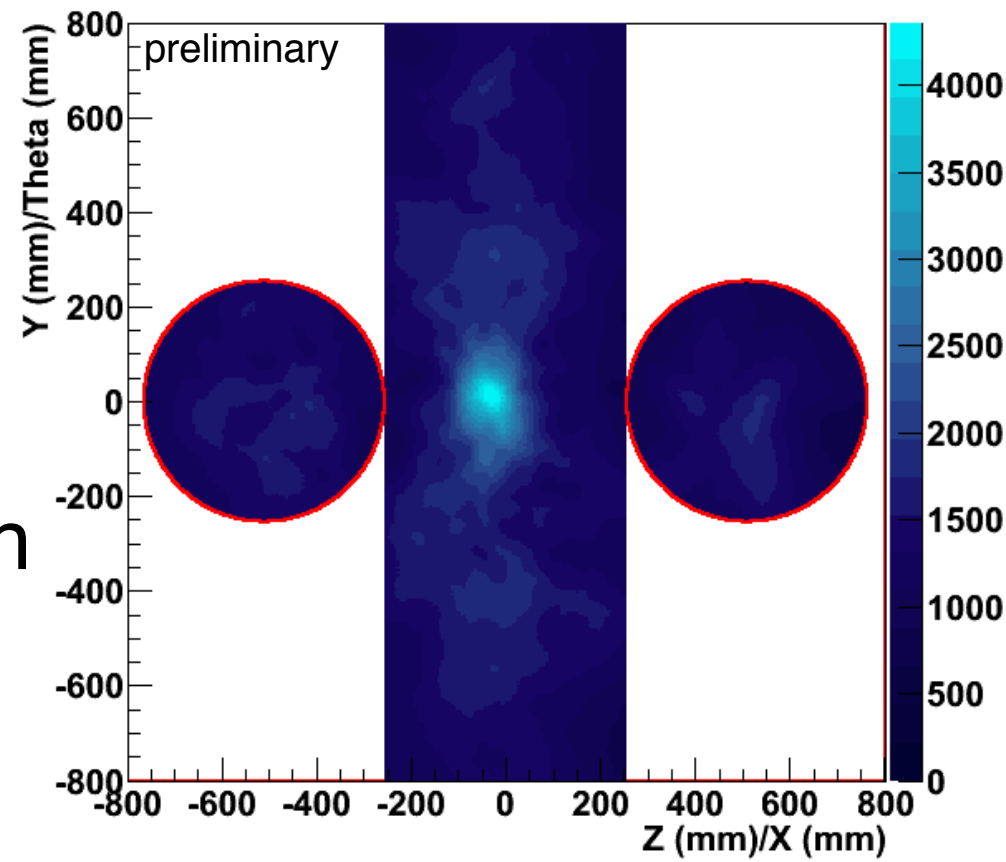


- Using Compton telescope technique, we can verify location of source
  - (Also for finding radioactive hot spots)

- Detector measures energy and location

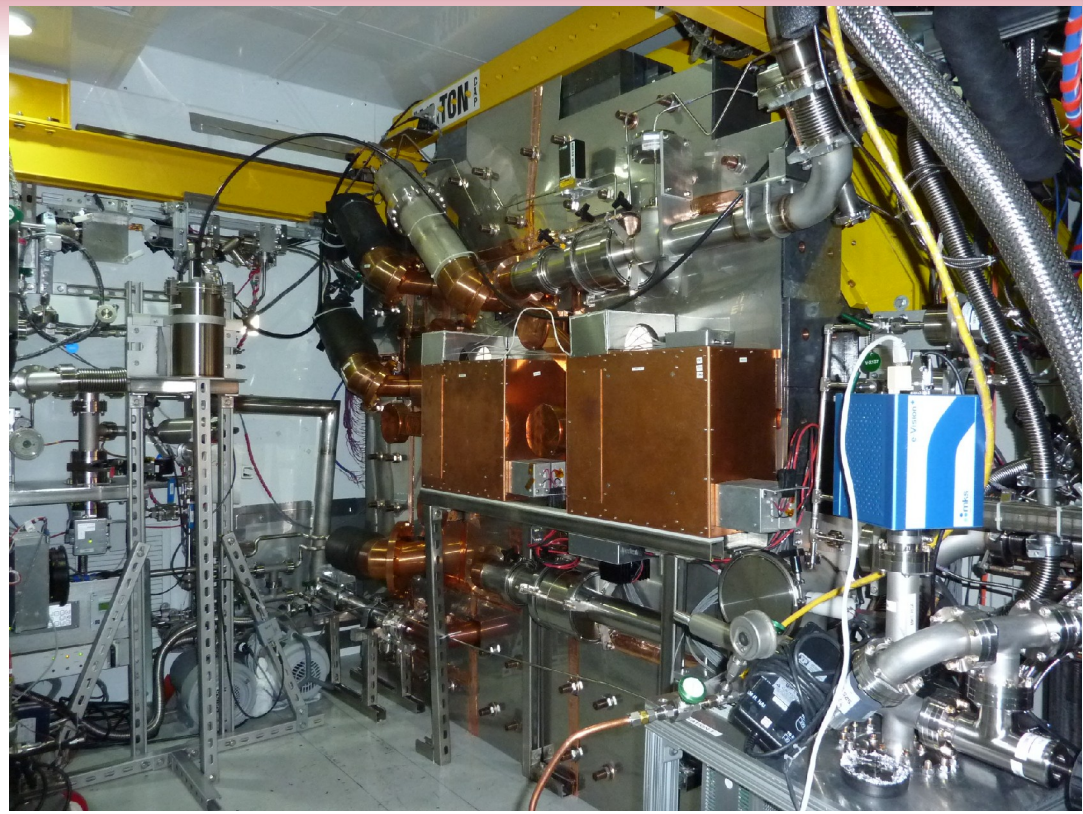
$$\phi = \arccos\left[1 - m_e c^2 \left(\frac{1}{E_\gamma - E_1} - \frac{1}{E_1}\right)\right]$$

- This gives a cone from each site, add up to produce plot on right



Conclusions and Status

- Detector operates well!
- We are beginning to understand detector
- We have techniques to understand backgrounds and calibrate detector once we begin taking physics data



- Current status:
  - Paused to get into low background mode (front Pb wall, Rn enclosure, muon veto)
  - Filled with xenon again
  - Physics data taking ~now

The EXO Collaboration

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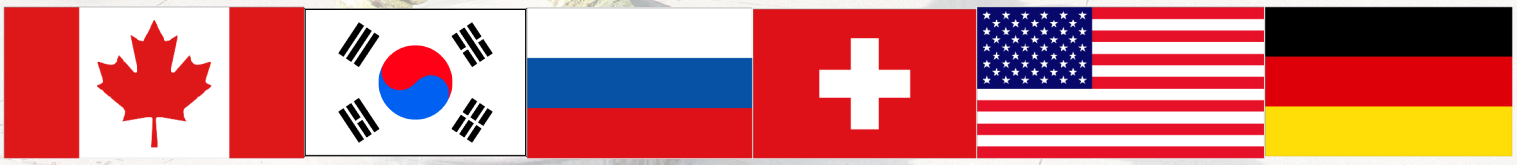
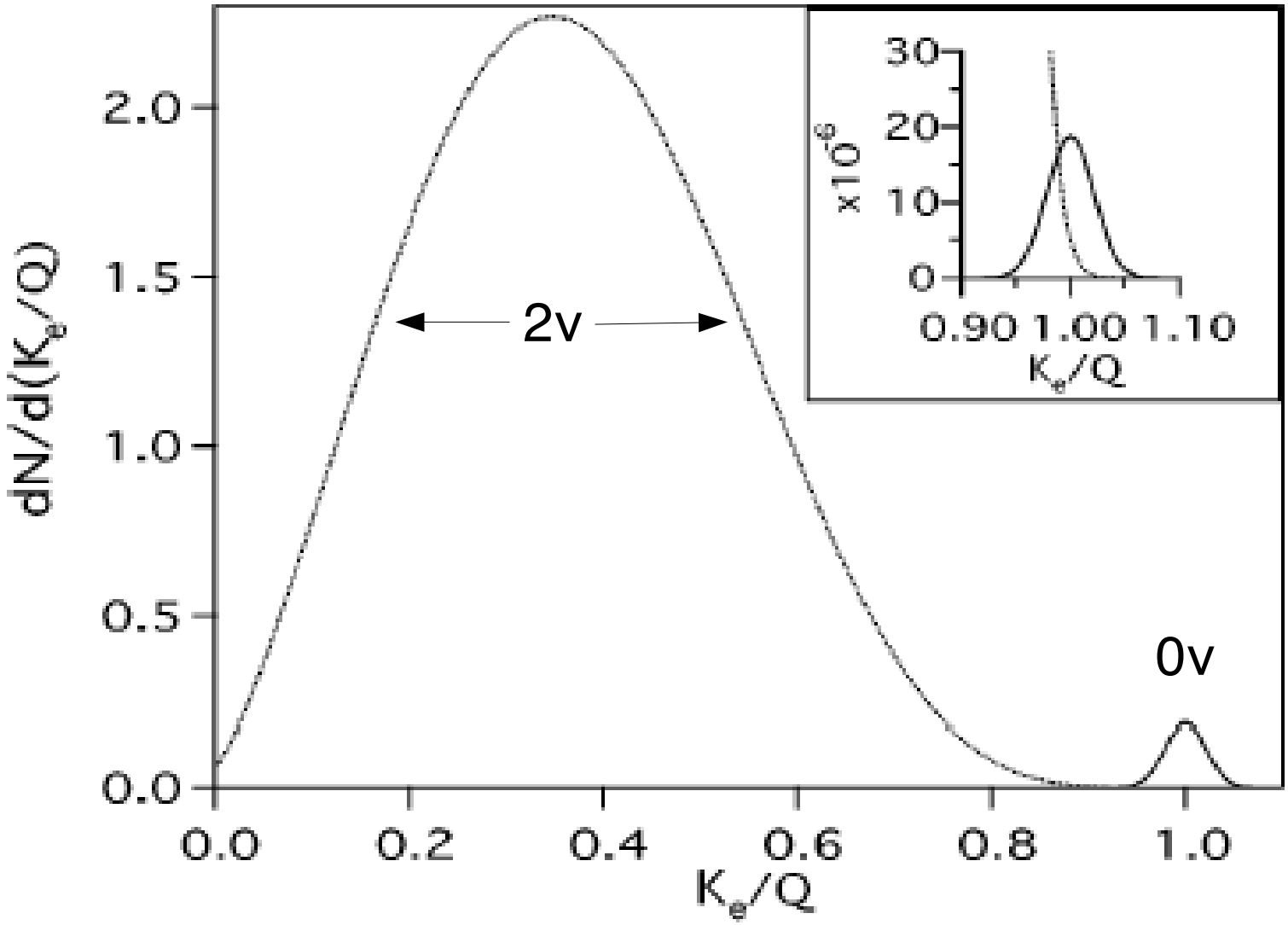


Backup Slide 1: Sensitivity

Case	Mass (ton)	Eff. (%)	Run Time (yr)	σ_E/E @ 2.5MeV (%)	Radioactive Background (events)	$T_{1/2}^{0\nu}$ (yr, 90%CL)	Majorana mass (eV) QRPA	NSM
EXO-200	0.2	70	2	1.6	40	6.4×10^{25}	0.133†	0.186*

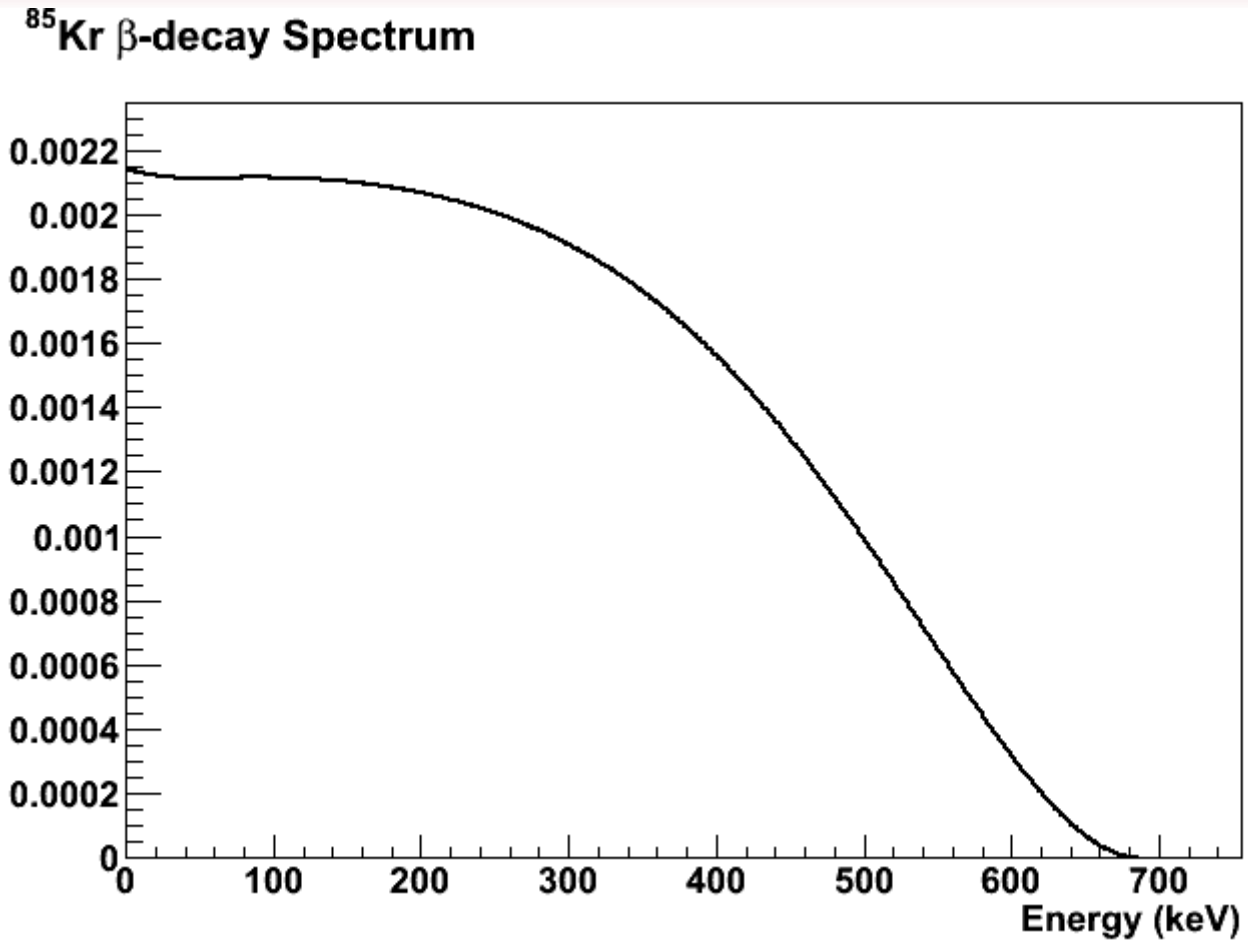
† Rodin, *et. al.,* Nucl. Phys. A 793 (2007) 213-215
*Caurier, *et. al.*, arXiv:0709.2137v1

Backup Slide 2: Double Beta Spectrum



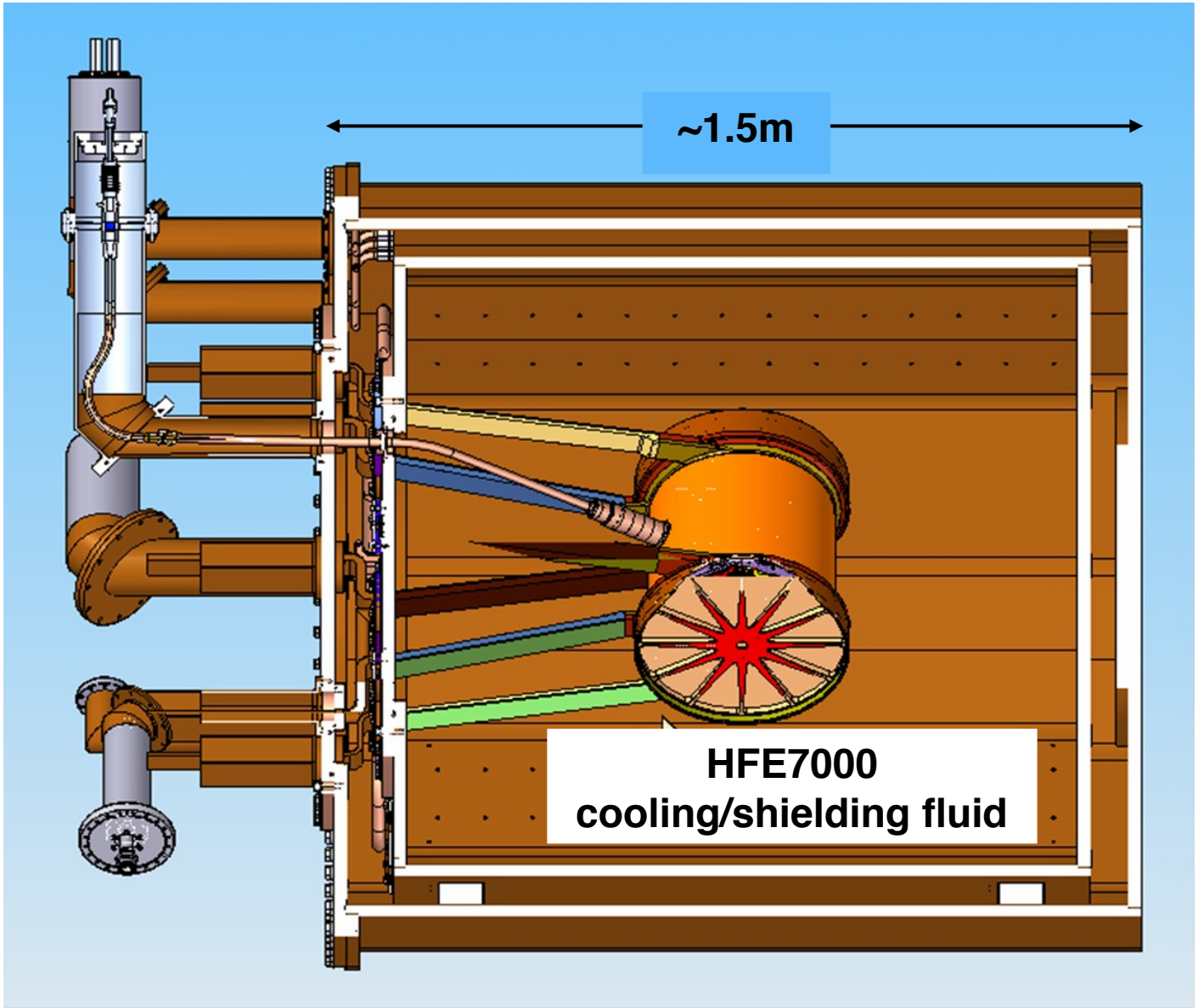
Elliot, S. et al., Annu. Rev. Nucl. Part. Sci. 2002. 52:115–51

Backup Slide 3: ^{85}Kr

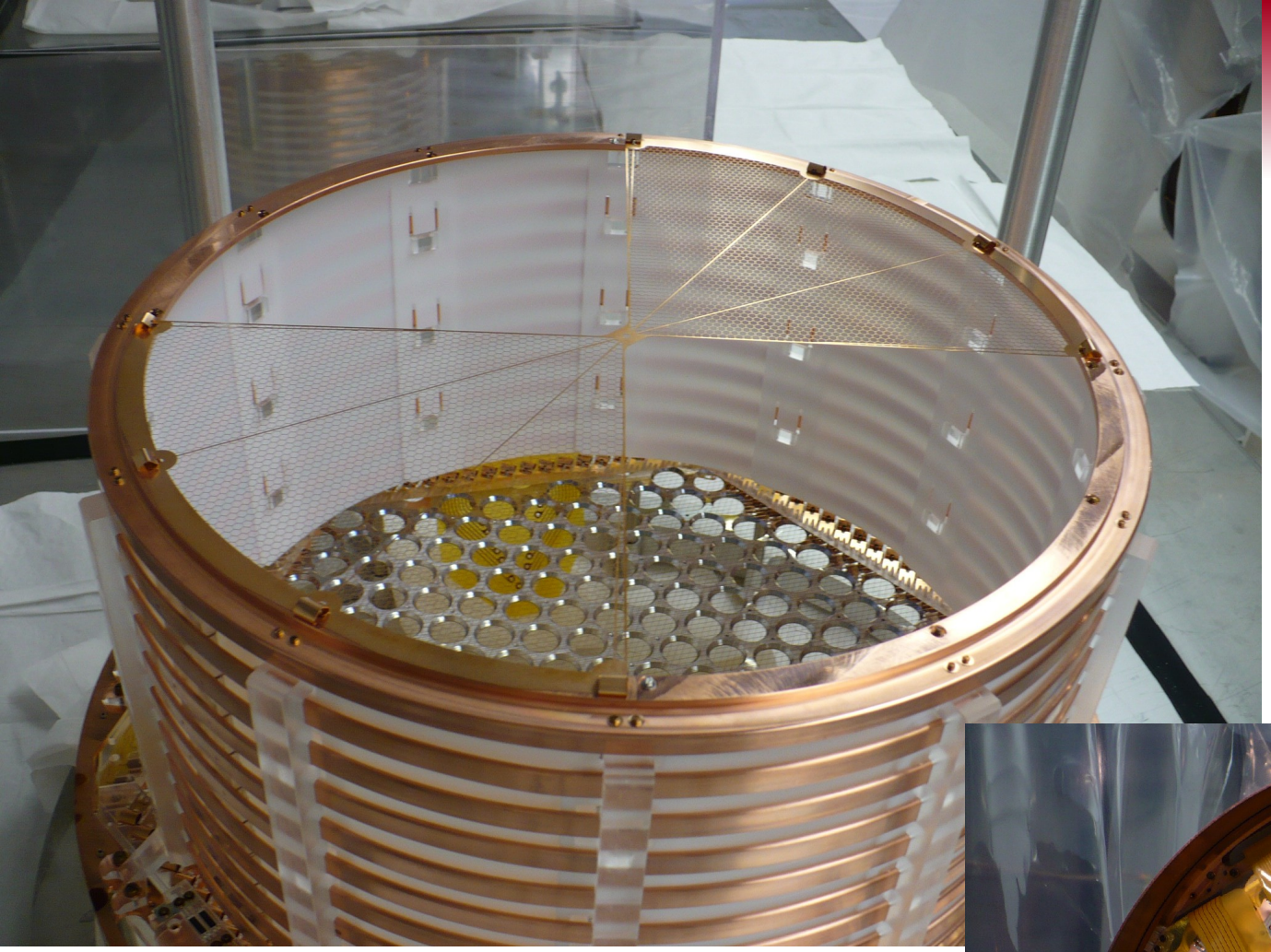


Beta decay of ^{85}Kr is unique first forbidden

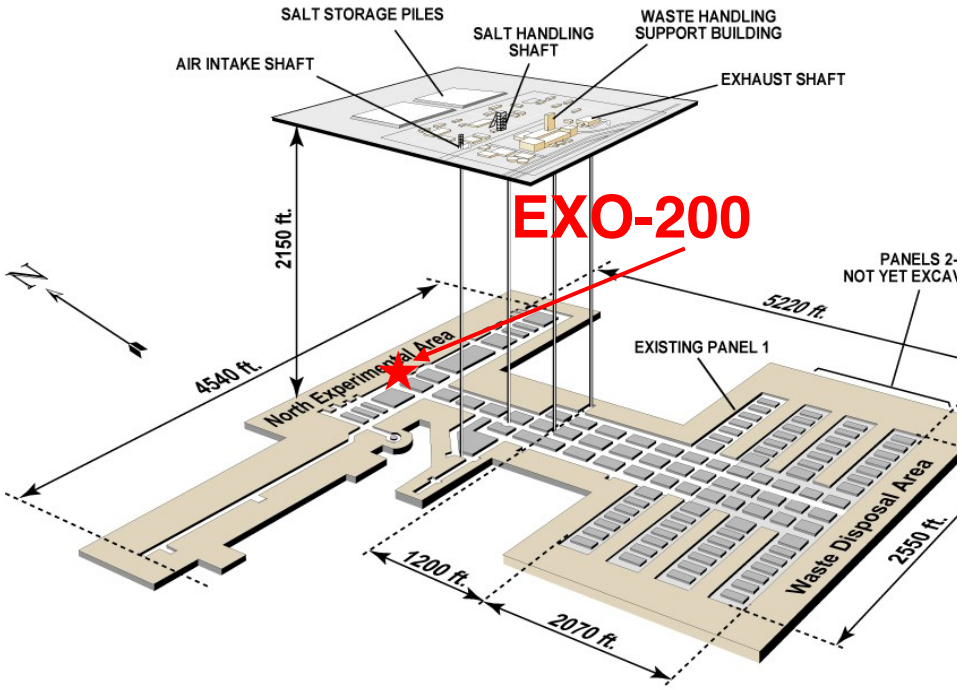
Backup Slide 4: Cryostat



Backup Slide 5: TPC Internals



Backup Slide 6: Pictures



WIPP Site