Dark Matter Calibration

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Liquid Argon TPC R&D Workshop

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Fermilab

Berkeley Lab

Outline

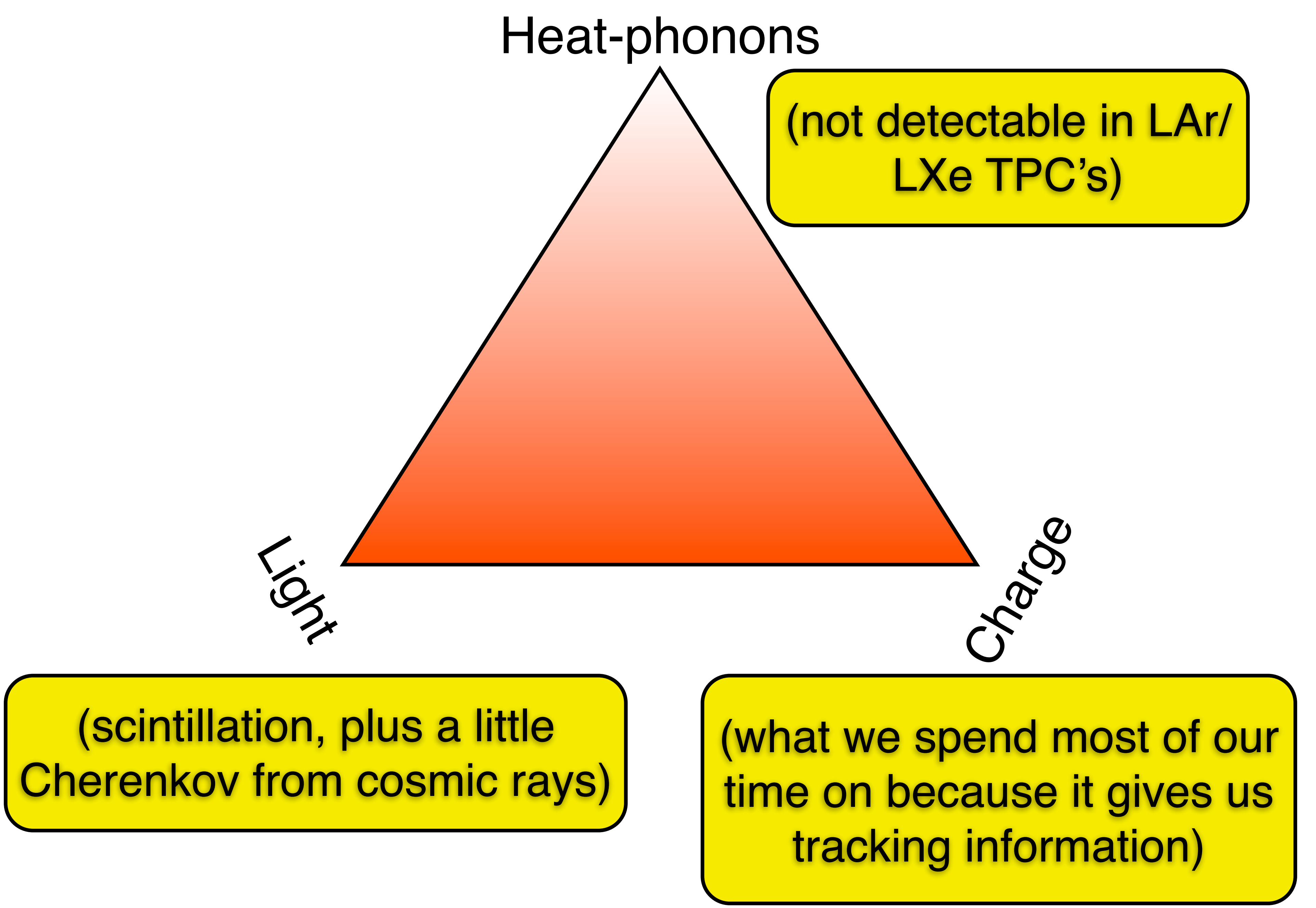
- Remember what the signal is!
- What do we need to calibrate?
  - Energy scale
  - Position reconstruction
  - Nuclear vs. electron recoil discrimination
  - Correlation between active veto and main detector

The dark matter signal

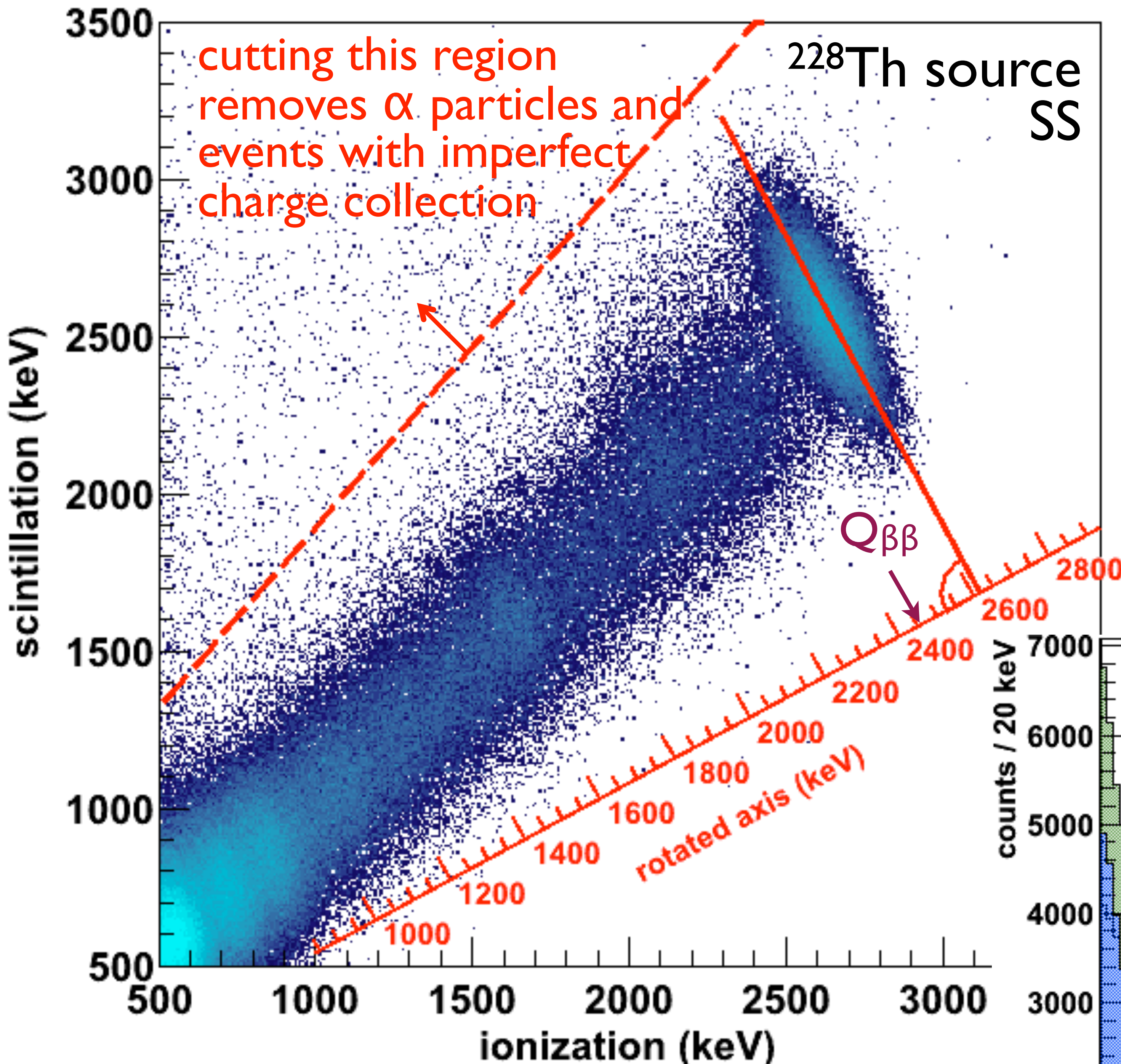
- When searching for WIMP dark matter, your signal is a set of single, uncorrelated, low-energy nuclear recoil events
- Can also try to look for
  - Annual modulation in the overall rate and spectrum shape
  - Diurnal modulation in track direction
- Both of these are really hard, so we'll focus the rest of the talk on "single, uncorrelated, low-energy nuclear recoils"

Energy Scale

- Three channels for detecting energy deposition in TPC's:



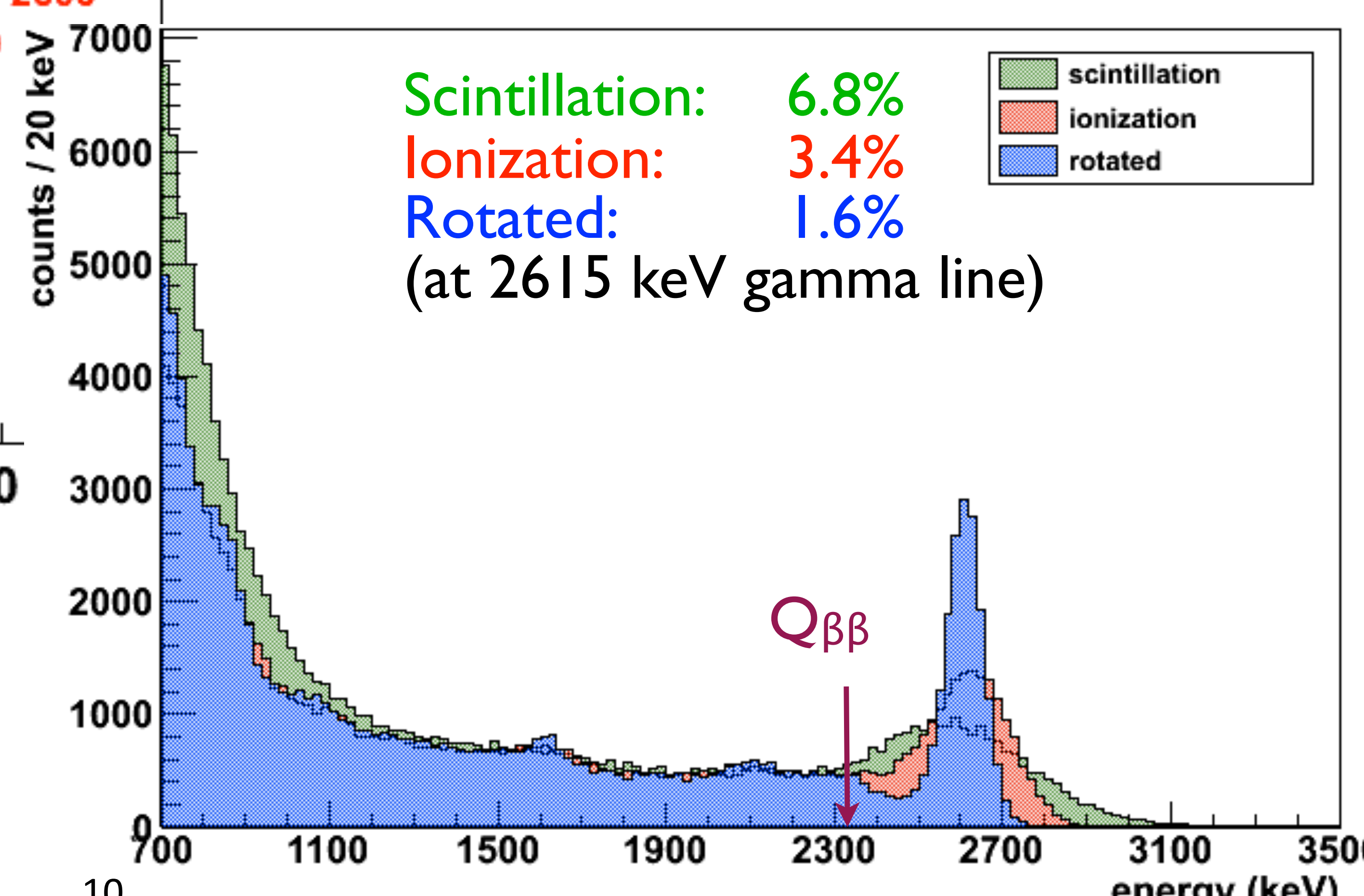
Combining Ionization and Scintillation



Properties of xenon cause increased scintillation to be associated with decreased ionization (and vice-versa)

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

Use projection onto a rotated axis to determine event energy



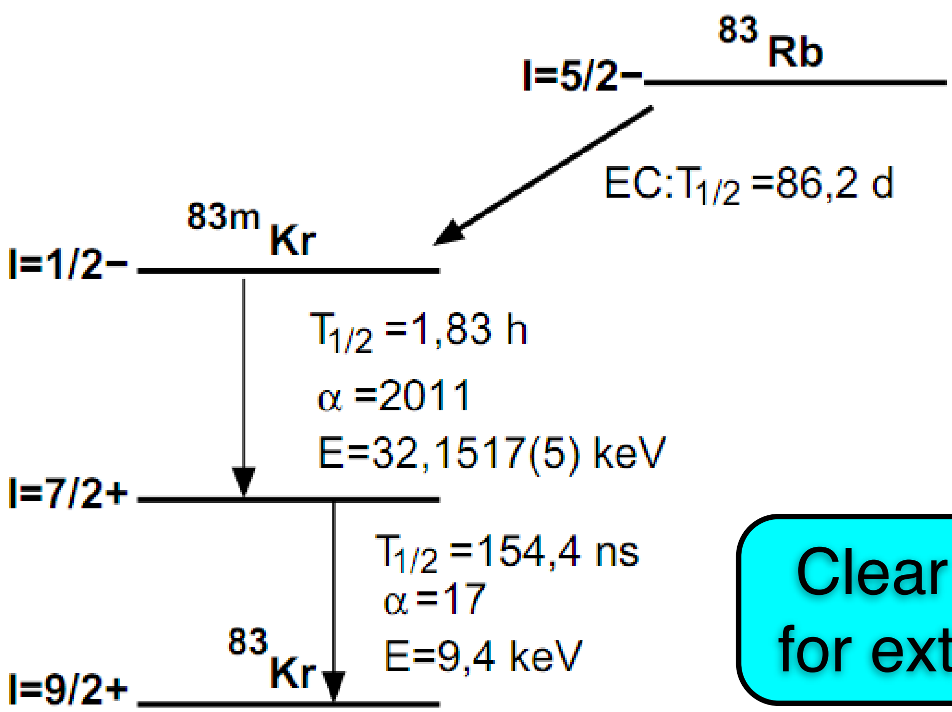
Rotation angle chosen to optimize energy resolution at 2615 keV

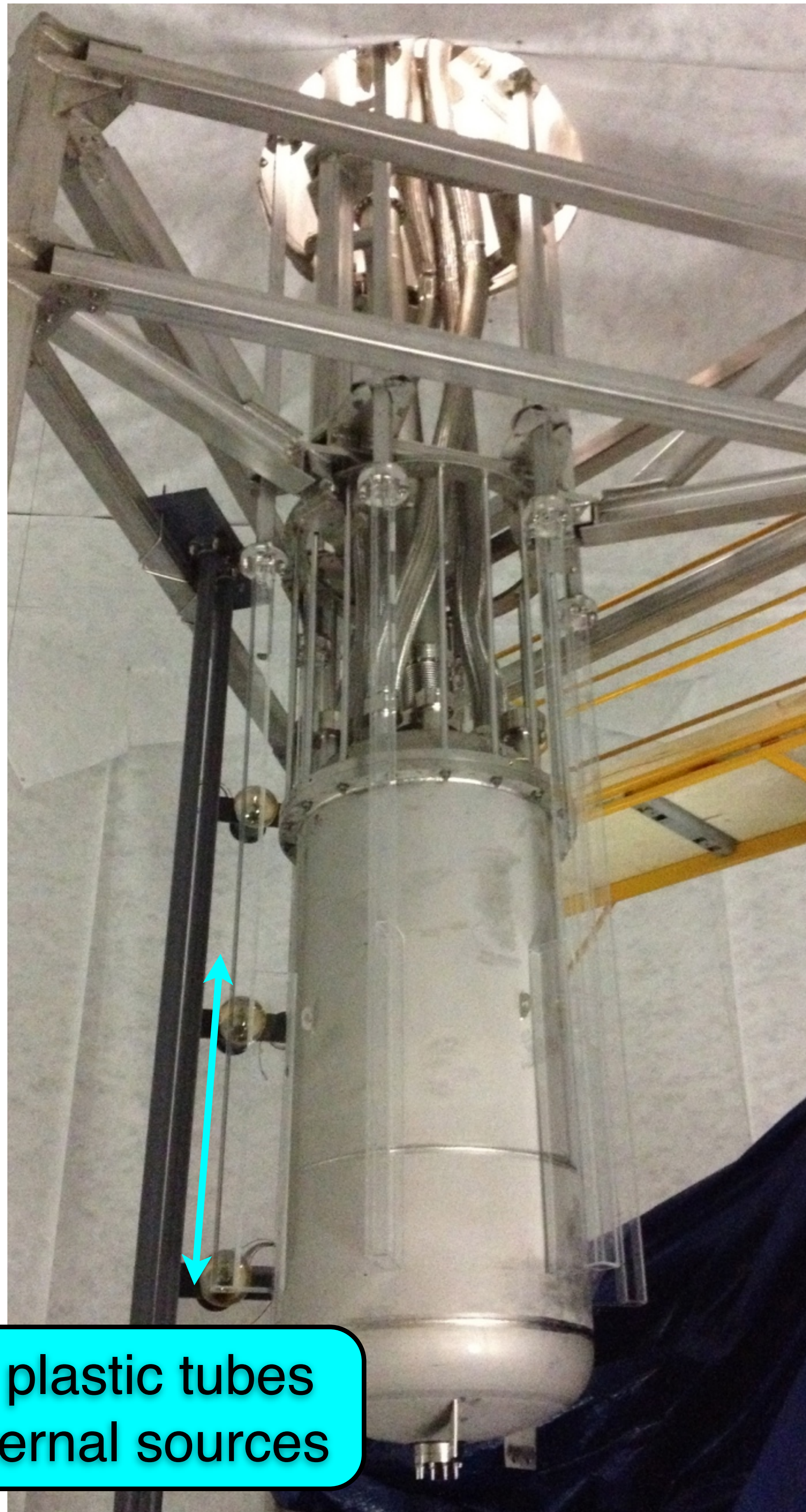
Slide from Jacques Farine, Neutrino 2012

How is it done?

- Both position and energy calibration are done with a combination of:
    - External sources (both neutrons and gammas)
    - Internal sources (must be short lived, but not too short...)

A ^{83}Rb source inline with your purification system gives you ^{83m}Kr, a uniformly distributed internal source!





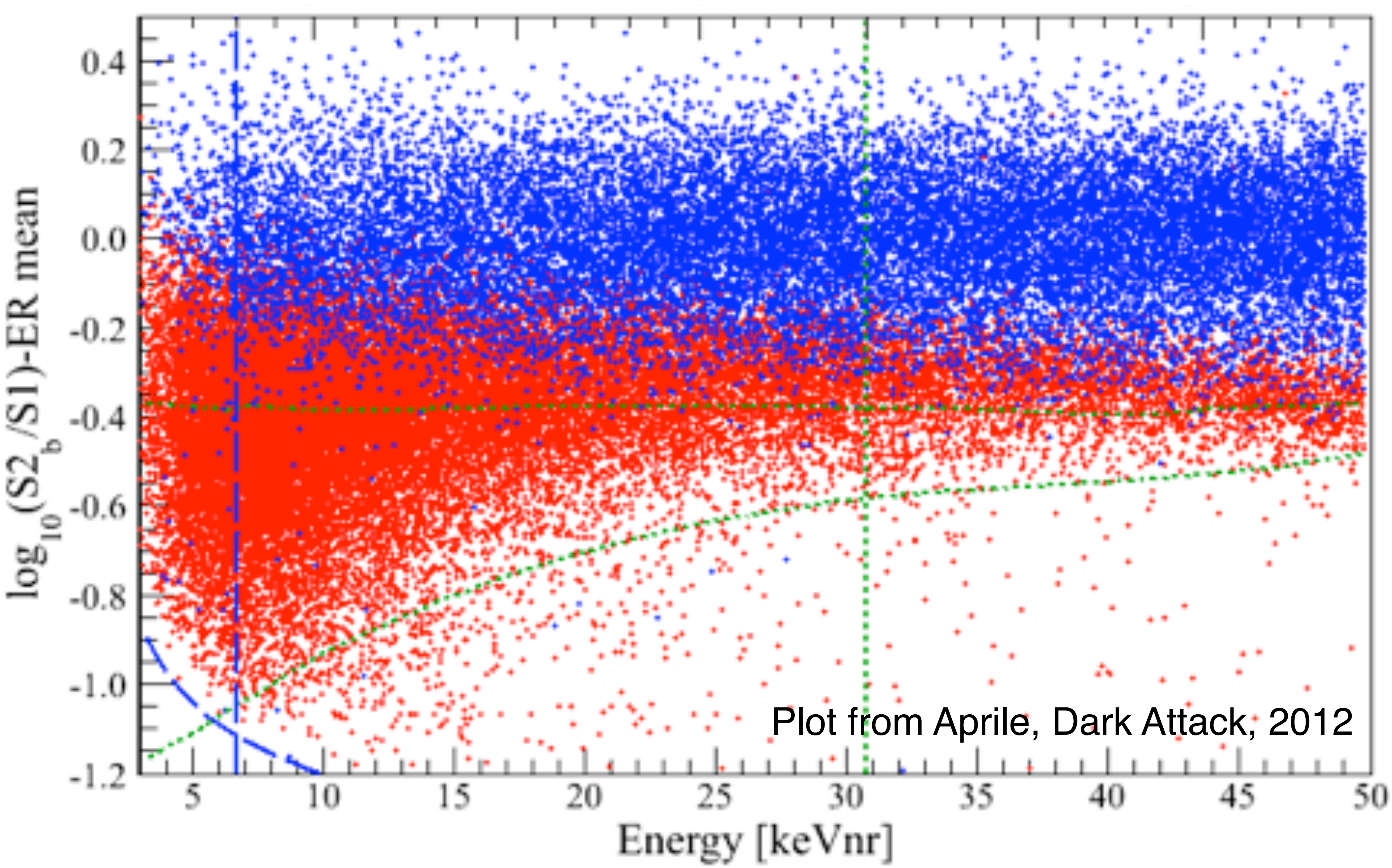
Clear plastic tubes for external sources

Position Reconstruction

- TPCs are imaging detectors--everything flows from position reconstruction!
- It would be nice to have perfectly localized quanta of charge to inject around your detector, but usually people do this with external sources and surface events
    - Match radial profile of external source gammas
    - Look for known surface events (like radon)
    - Compare to simulation and analytic calculations
    - Also check distribution of internal source events

Particle ID

- Nuclear recoils (signal) give a different light to charge ratio than electron recoils (background)
- Also changes the time structure of scintillation light



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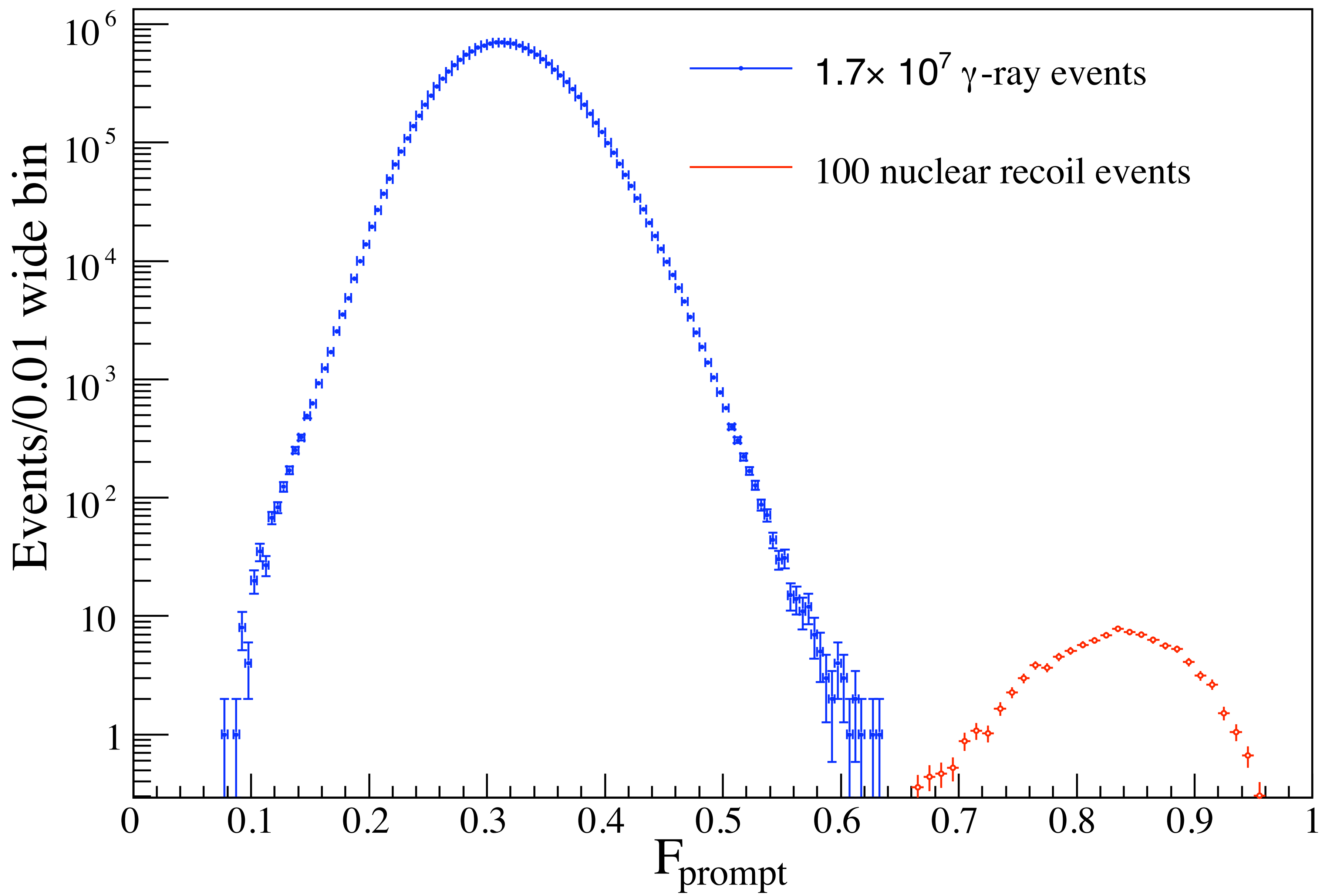
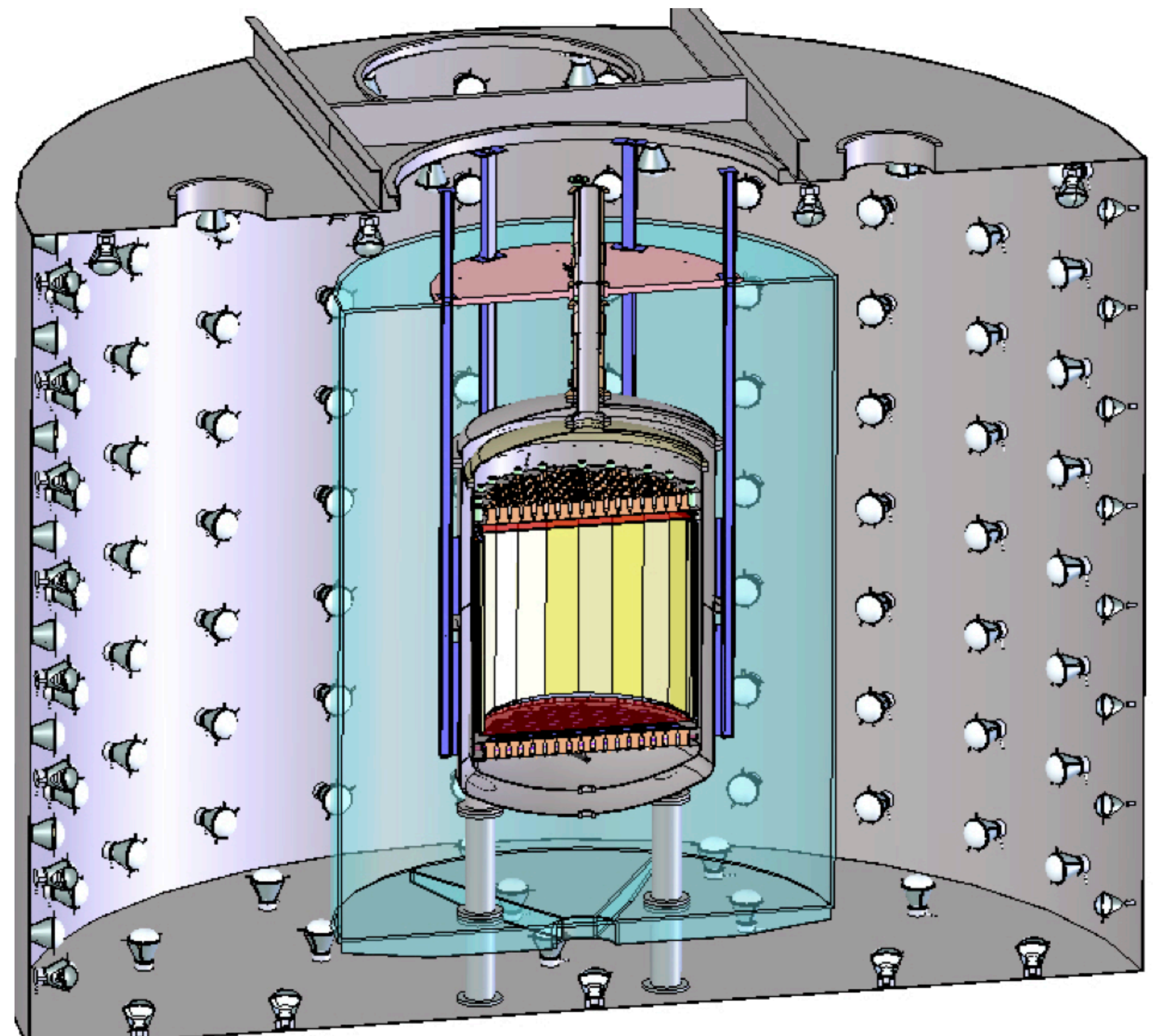


Correlation with veto

- Dark matter events should clearly only be in the active detector, not in the veto
- Current experiments mostly have passive or water Cherenkov shielding
- Next generation experiments will have much more sophisticated active veto systems
- Potential to use external neutron sources to measure nuclear recoil quenching factor with coincidences between main detector and reconstructed events in veto




Thank you for your attention
Any questions?