Background model updates since MCC11/TDR

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On behalf of the University of Sussex group

FD Sim/Reco Working Group Meeting, 25/Oct/2021

Outline

- We’ve been working on updating the low energy background model for DUNE
- Today’s highlight:
  - Decay0
  - Neutrons
  - Electronics noise

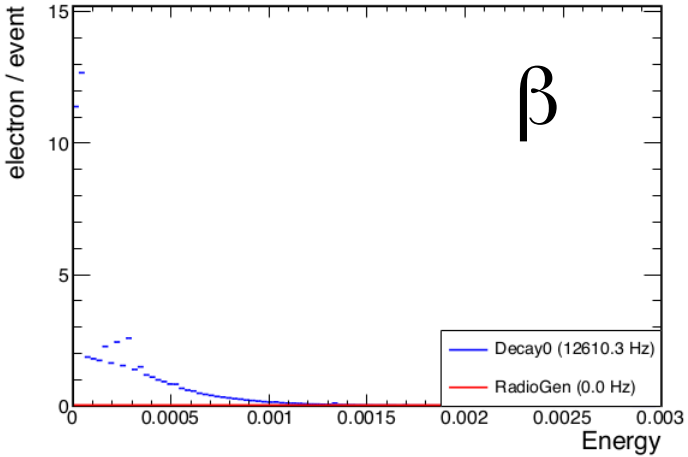
Decay0

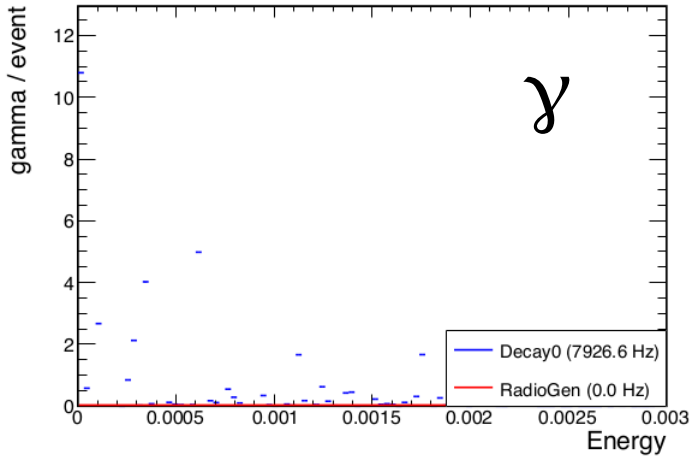
Decay0

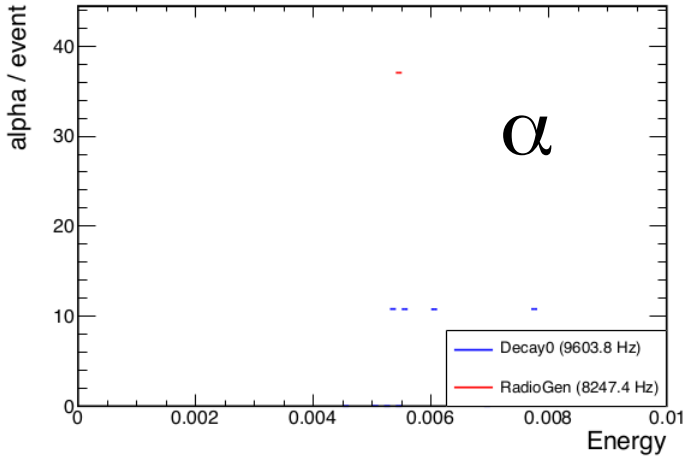
- Used for SuperNEMO, NEMO3 and others, to simulate $2\beta2\nu$ and background events
- For DUNE: radiological background events
- Implemented in *dunetpc*, with *larsimrad*, and validated
  - Pierre's talk at collab. meeting here

^{238}U chain

- Full ^{238}U chain on LAr, APA, CPA, PDS
  - RadioGen was 4 alphas of 5 MeV







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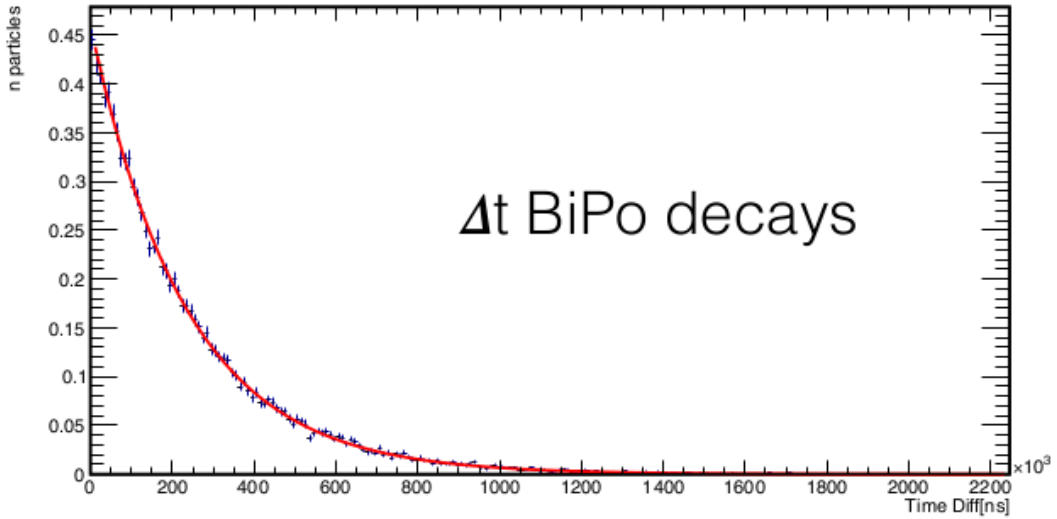
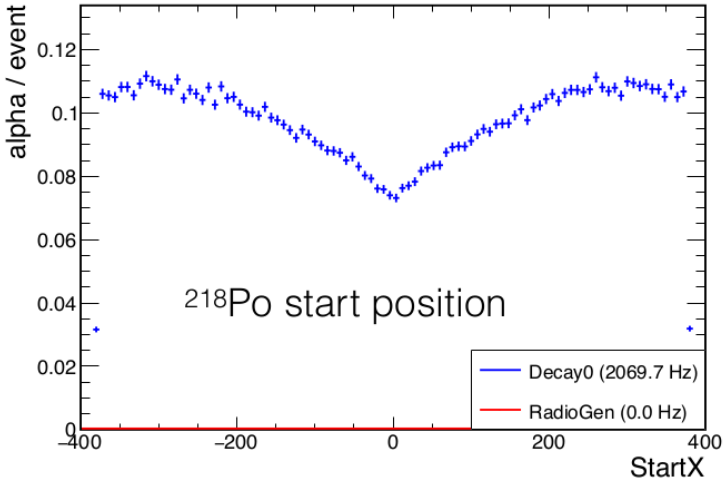
  - Decay0 generates time correlated decays (BiPo)

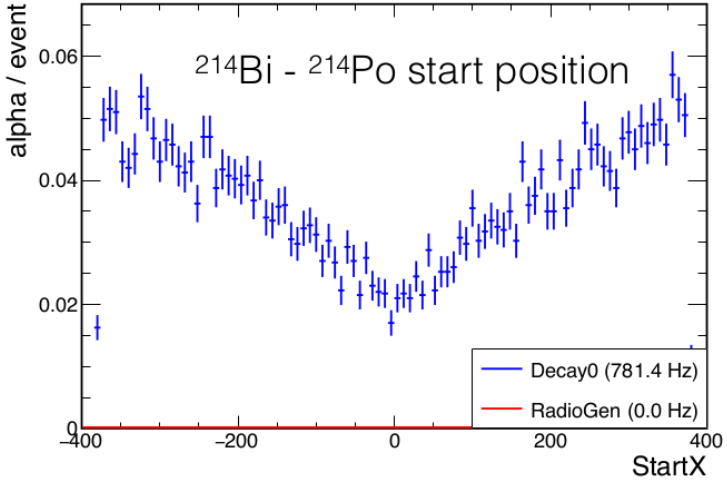


^{238}U chain

- Full ^{238}U chain on LAr, APA, CPA, PDS
  - RadioGen was 4 alphas of 5 MeV
  - Decay0 generates time correlated decays (BiPo)
  - Ion transport included (from Anyssa, here)

Ion	Cathode fraction
^{218}Po	13.68%
^{214}Pb	40.7%
^{214}Bi, ^{214}Po and ^{210}Pb	67.26%
^{210}Bi and later decays	100%





^{42}Ar

- 80% expected to reach cathode

$$^{42}Ar \xrightarrow[600\,keV]{33\,y} {}^{42}K \xrightarrow[3.5\,MeV]{12\,h} {}^{42}Ca$$

- This 80:20 non-uniformity included in Decay0

Missing bits

- Volumes
  - Field cage
  - APA electronic boards (need to add MC geometry)
- Isotopes
  - ^{232}Th chain (APA, Field cage, etc)

Decay0 @ dunetpc

- Current at *feature/plasorak_bgd_validation* branch of *dunetpc*
- Sample generation fcl:
  - prodbackground_radiological_decay0_dune10kt_1x2x6.fcl

Neutrons

Radiological neutrons

- For TDR, simple FD geometry was considered
  - 80 Hz of neutron captures on LAr volume
- Evaluated impact of all elements that also acts as shielding against neutrons
  - Aran updates on collab. meeting here

Neutron capture rate

	Rock	Shotcrete	Concrete	Total
Cellulose	3.06 ± 0.07	2.49 ± 0.03	0.13 ± 0.001	5.68 ± 0.08
New Wood	3.08 ± 0.07	2.49 ± 0.03	0.14 ± 0.001	5.71 ± 0.08

- Below the 10 Hz threshold for background rate in the DUNE FD
- Could be improved by the addition of neutron absorbing layers in the cryostat
- Neutrons have the biggest uncertainty
- Full geometry used for correct flux on the sides in 1x2x6 geometry

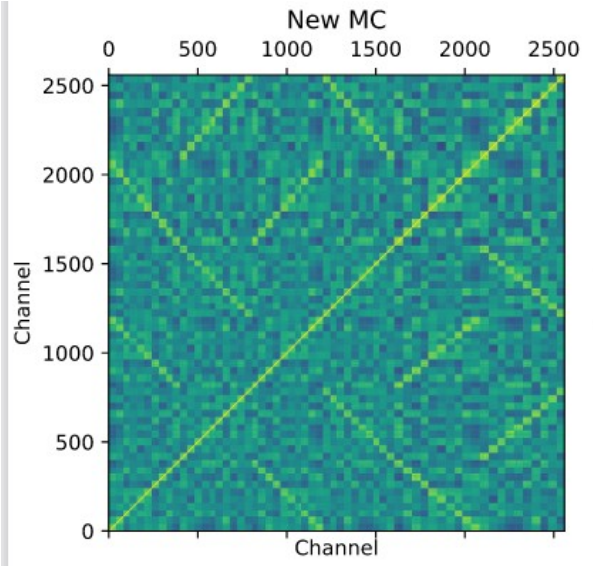
Electronic Noise Model

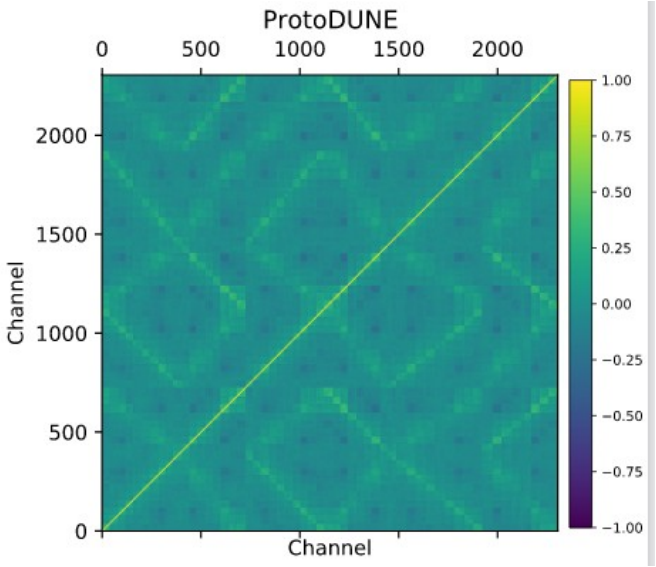
New noise model

- New noise (ProtoDUNE based) implemented
  - Includes:
    - Wire noise
    - Coherent noise
    - Digitisation noise
  - 3 types of ProtoDUNE data:
    - Low purity runs
    - Long readout runs with HV off
    - Normal runs

New noise model

- New noise (ProtoDUNE based) implemented
  - See Babak & Pierre's talk (here)





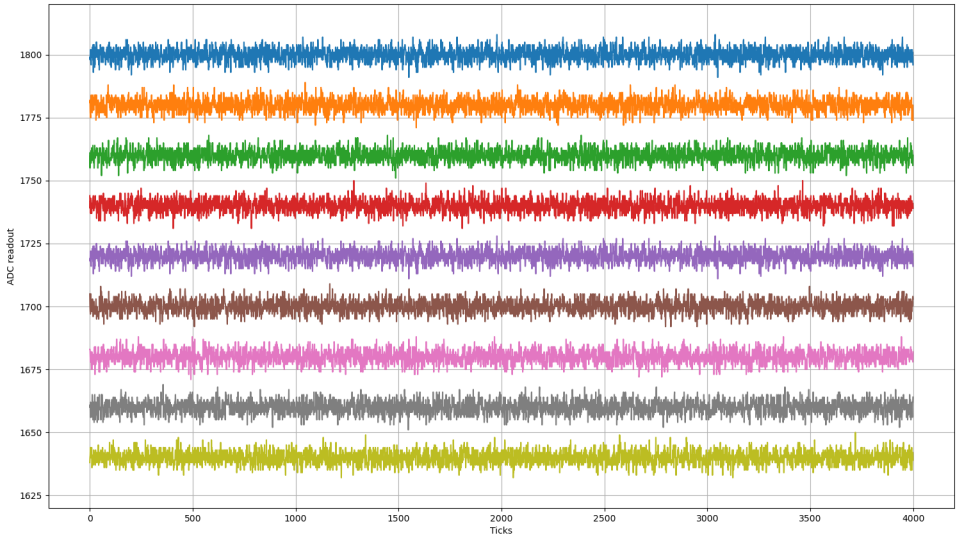
  - Already presented to the CE group (here)

New noise model @ dunetpc

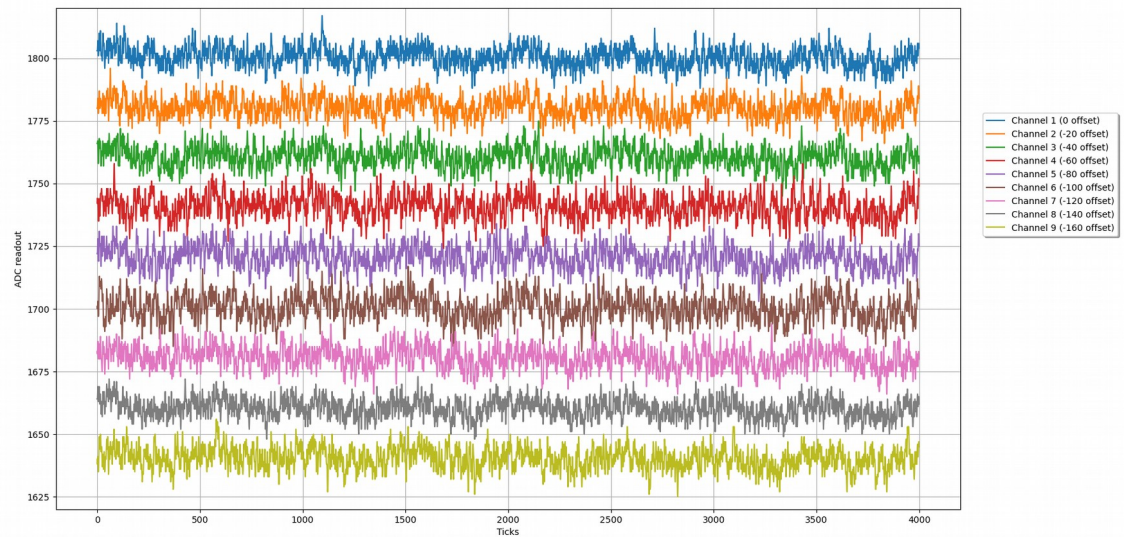
- Sample fcl in dunetpc
  - addprotodunelikenoise_findprim_snanas.fcl
  - Run with a “noiseless” *detsim* file as input
  - It also returns trigger primitives (hits, or pulses found) from the raw waveform

New noise model

Gauss Model (TDR)

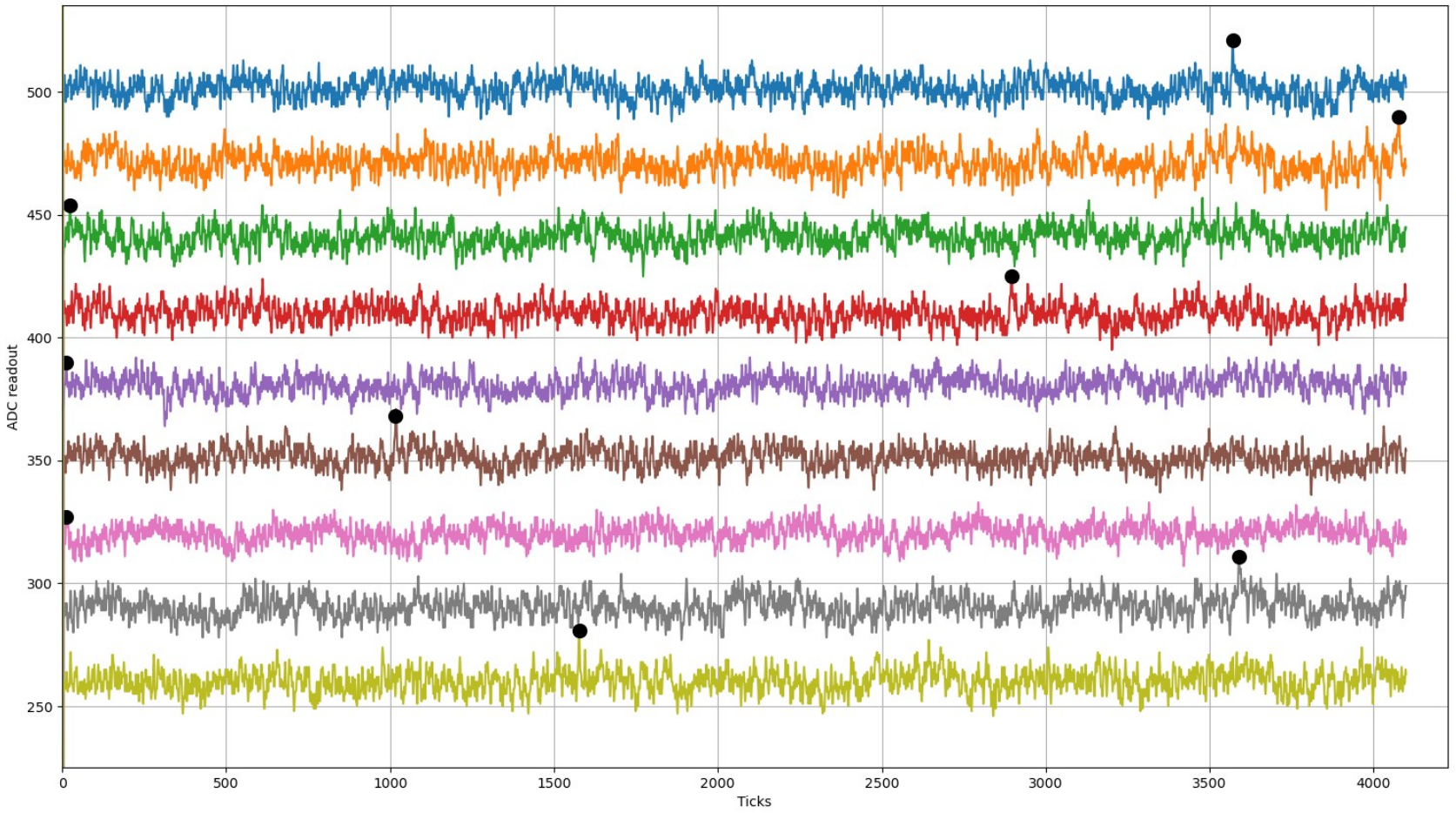


New Model (ProtoDUNE)



Correlated component included

Running TP finder

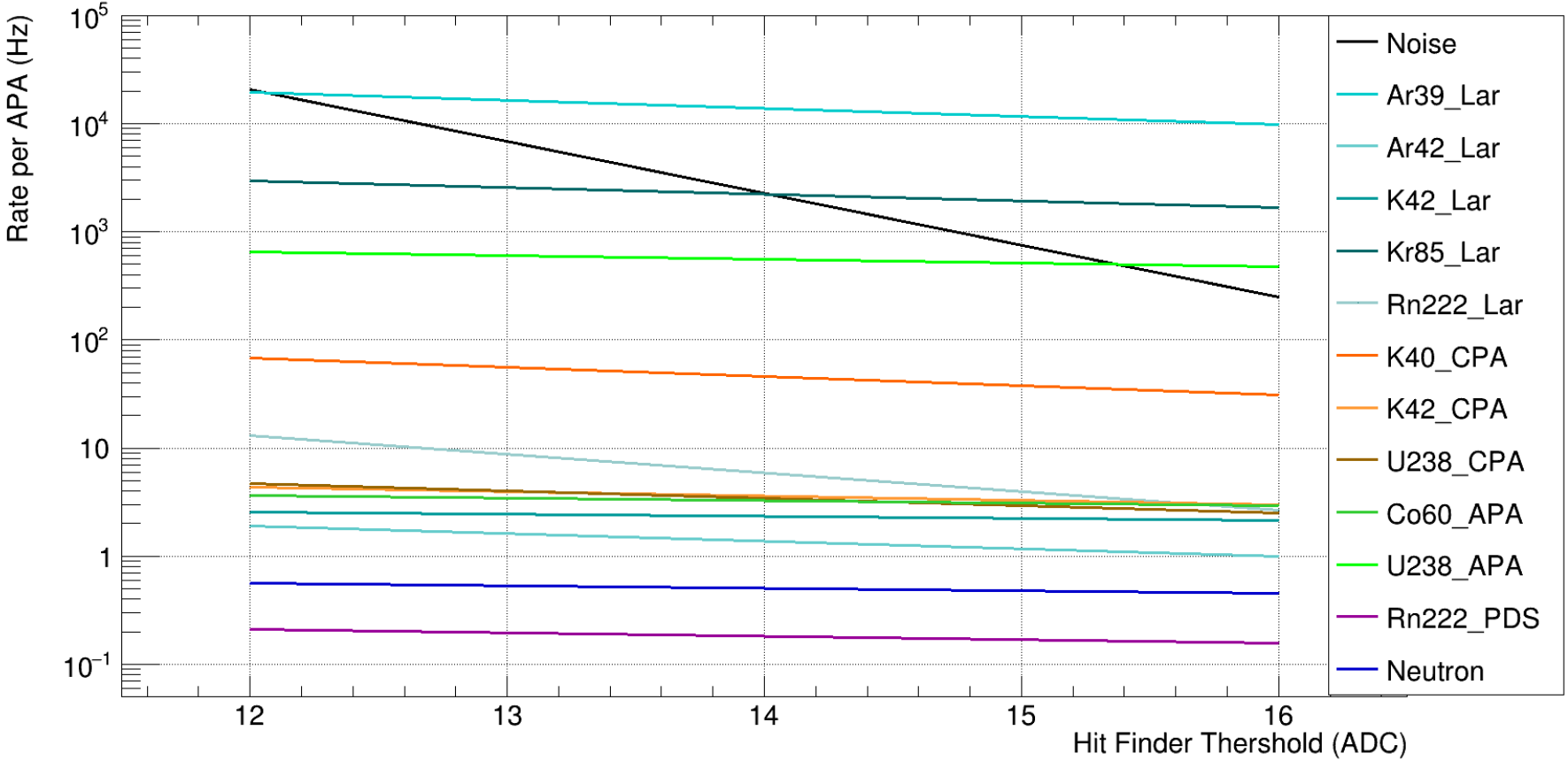


16 ADC threshold

From 0 MeV MC e⁻'s

Hit rates

Run full simulation chain: Gen → G4 → DetSim → Trig.Prim. Finder



Summary

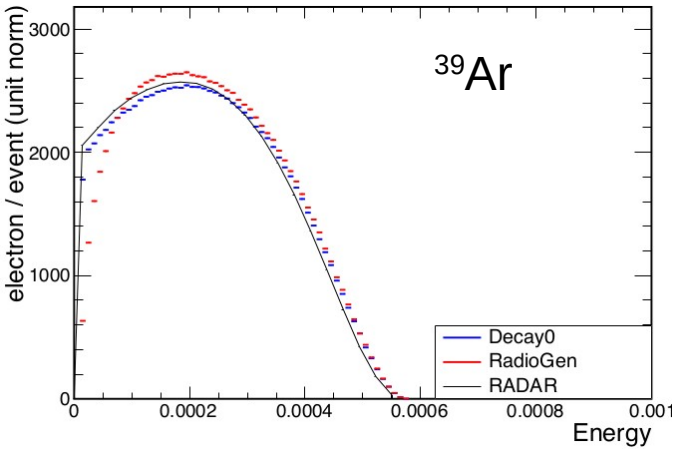
- Several updates w.r.t. TDR
- **Decay0**
  - More decays added (**full ^{238}U chain**, ^{42}Ar, etc)
  - **Better volume generation** (CPA, APA, PDS)
  - Ion transport included
  - Evolving note: DUNE-doc-23595
- **Neutrons**
  - Full simulation of FD module components
  - New energy spectra
  - Reduced capture rates in LAr volume w.r.t. TDR
  - Note with first results: DUNE-doc-22783
- **Noise**
  - Based on ProtoDUNE HD
  - Correlated component considered
  - Tech note: DUNE-doc-22962

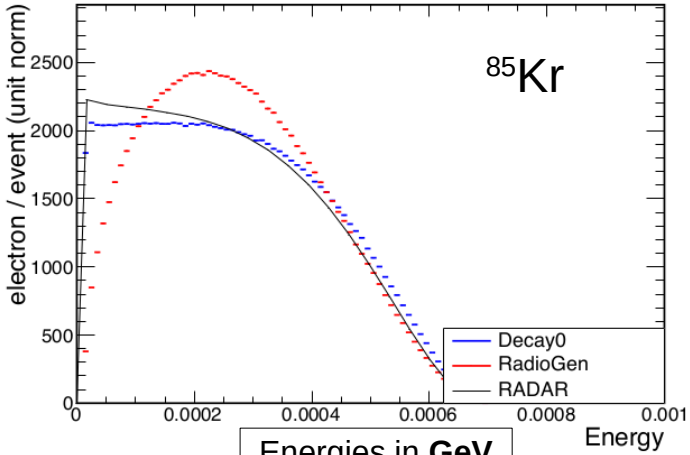
For discussion

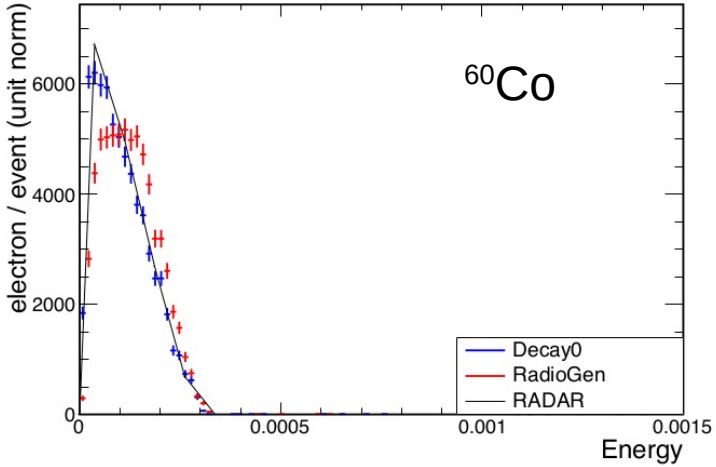
- MCC11 is out-of-date. Would be better to use Decay0 from now on. Best way to proceed?
- What is the status of alpha scintillation sim.?
- No information on the electronics boards on MC
  - Is there a plan to add?
- Electron lifetime: update it? (3 to 10 ms?)

Backup Slides

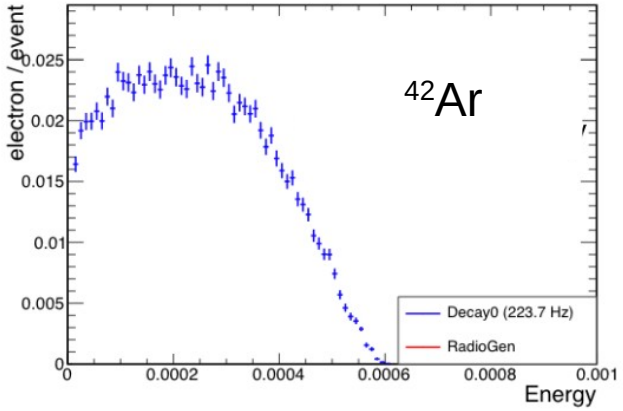
Shape of decays

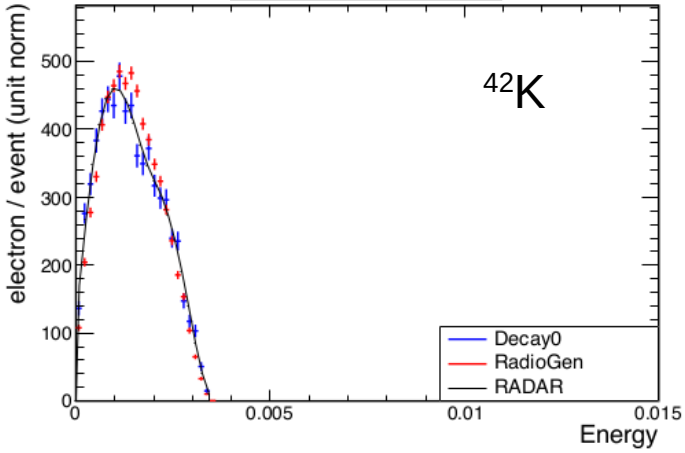


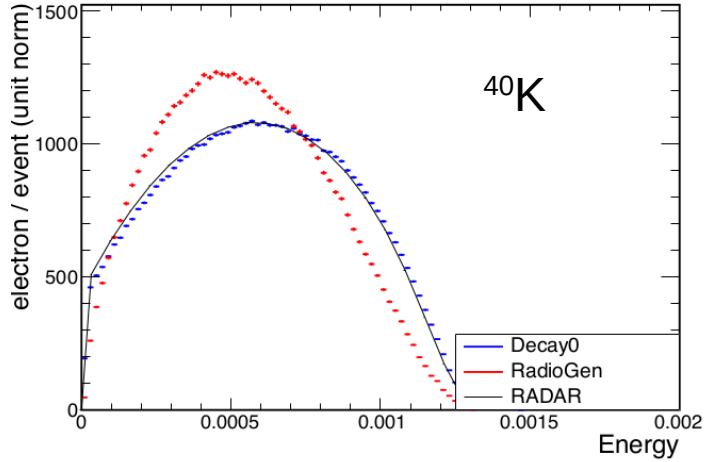




Energies in **GeV**



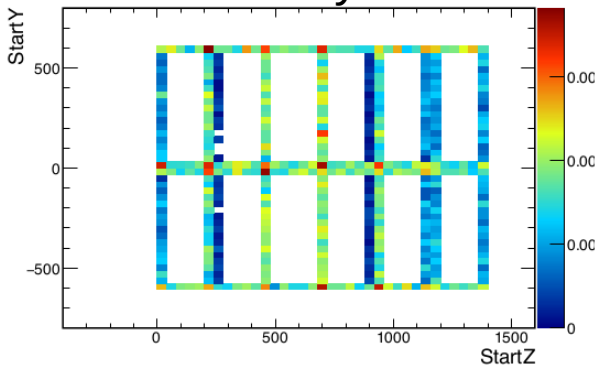




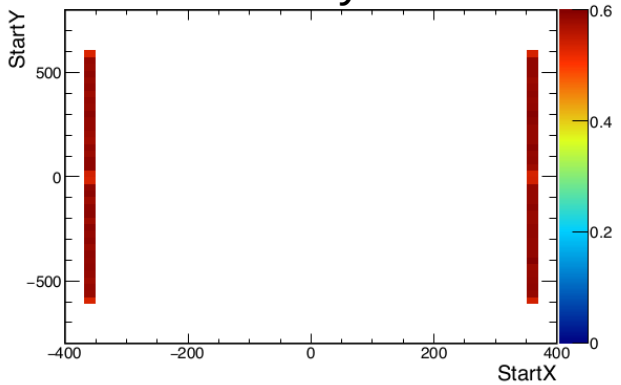
RADAR data available here

Position of decays

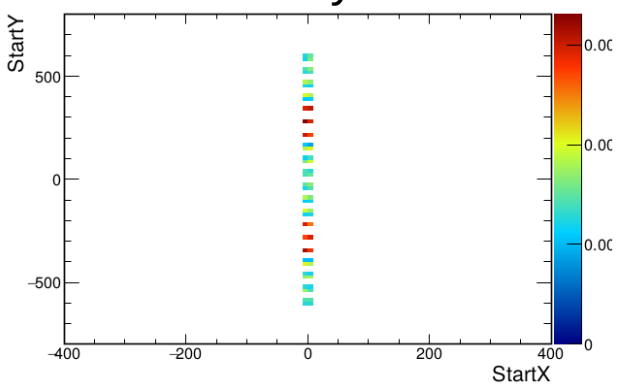
APA ^{60}Co Decay0



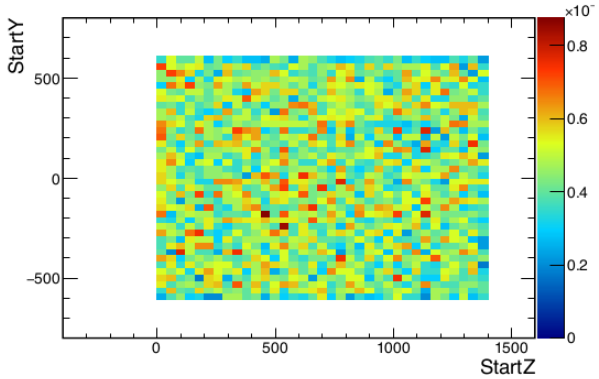
CPA ^{40}K Decay0



PDS ^{222}Rn Decay0



RadioGen



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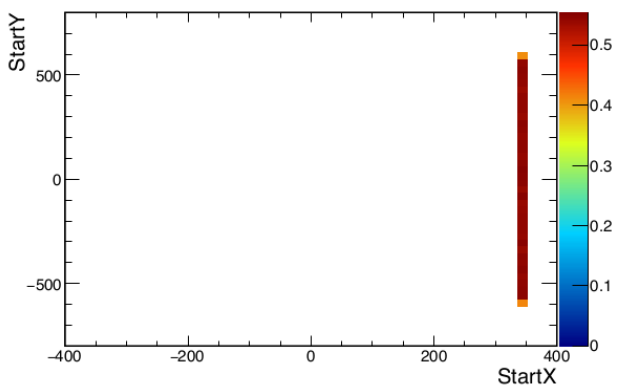

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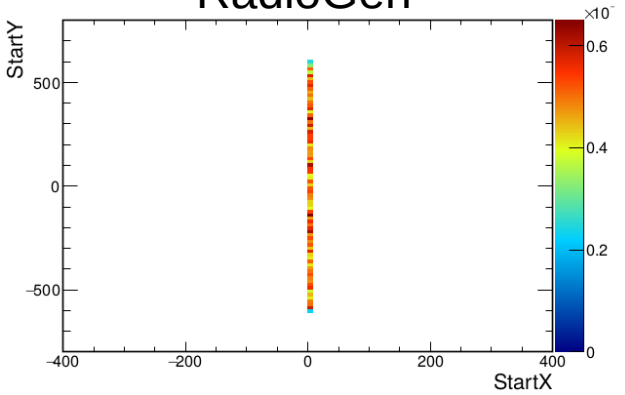
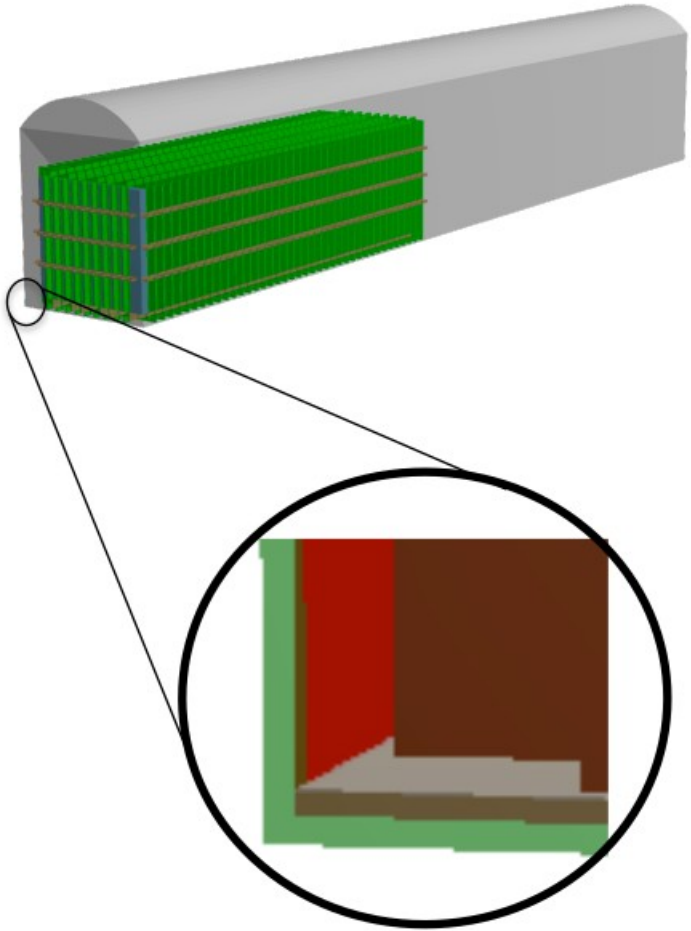


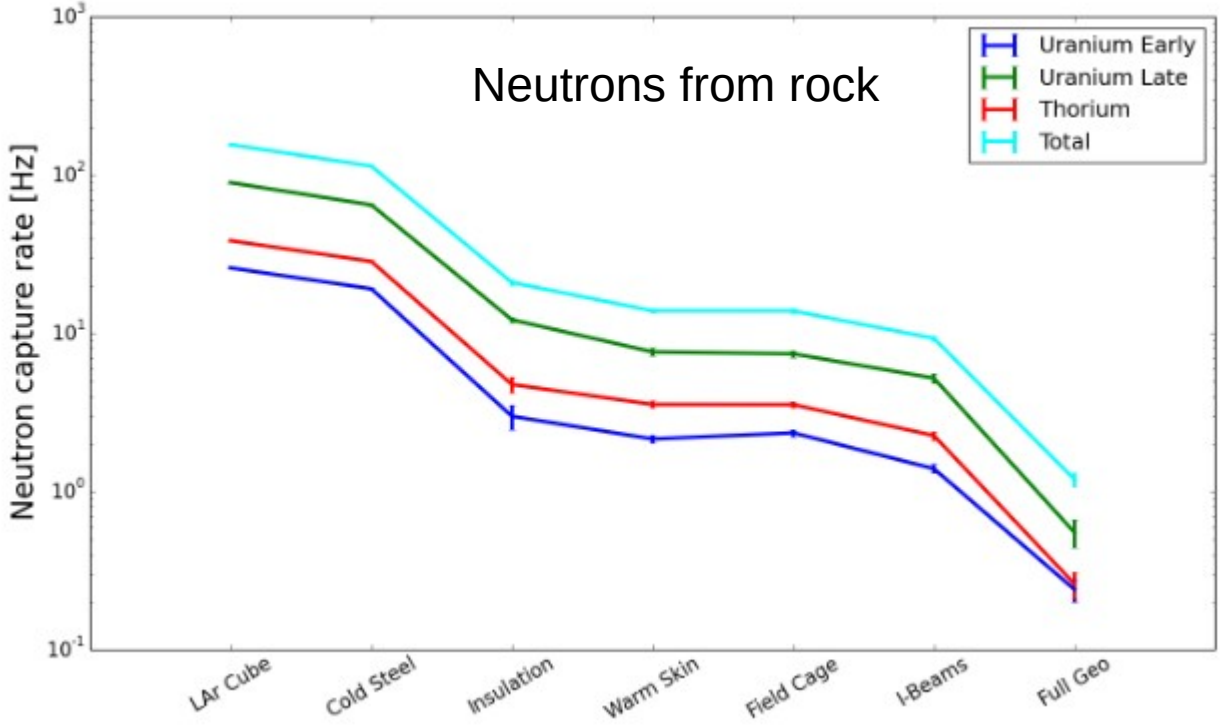
FD full geometry

- Designed with GeGeDe
- Dimensions from design and construction reports
- Materials definitions from spectroscopic methods (SDSMT)
- Rock average atomic composition from mine samples
- Concrete and shotcrete included



Neutron capture rate

- Neutron attenuation when adding layers

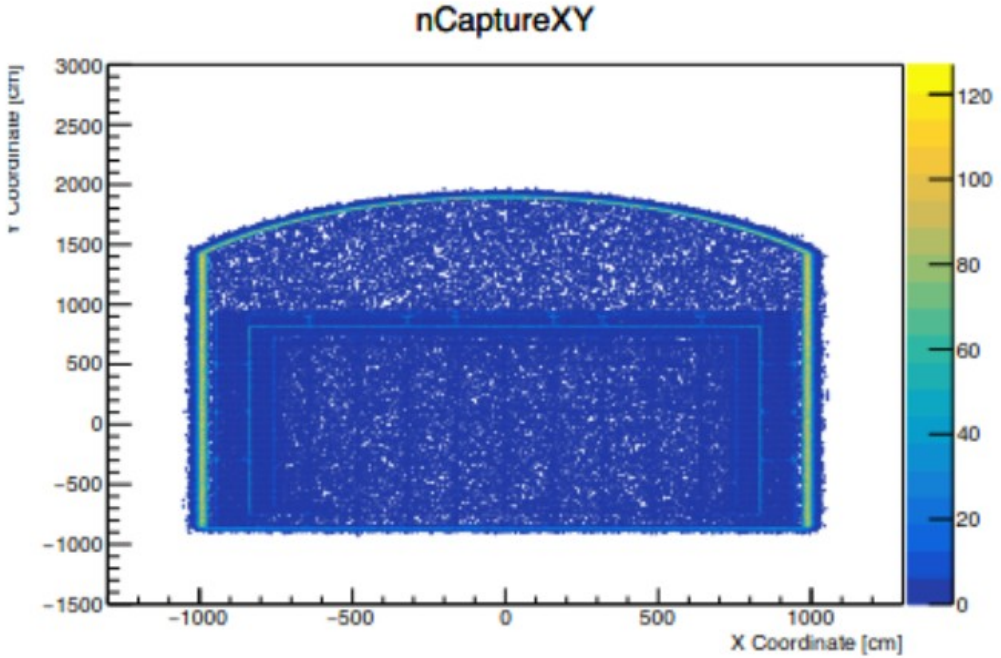


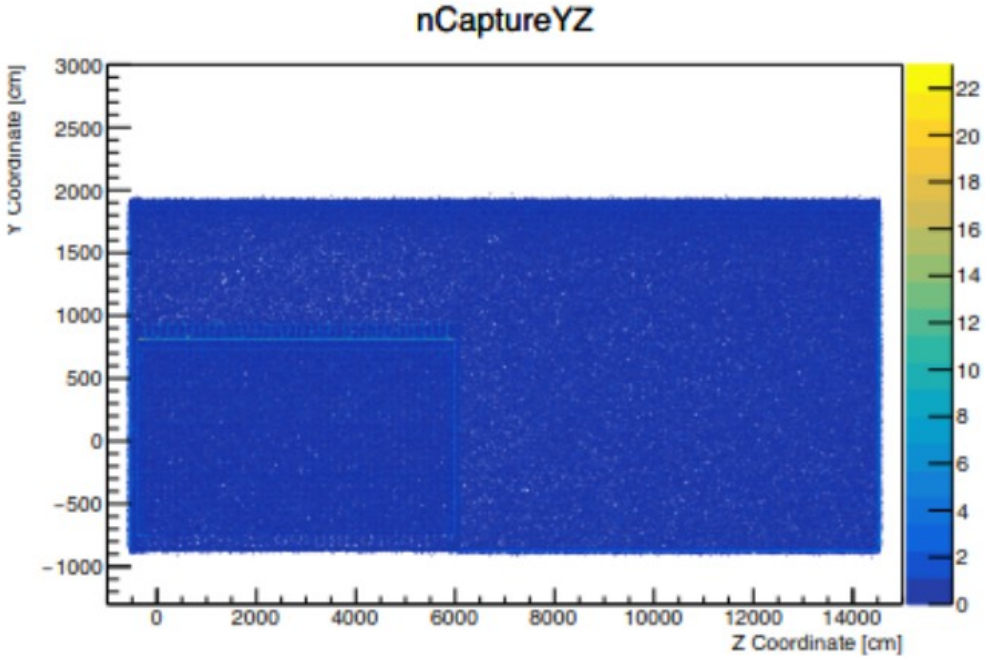
	Capture rate [Hz]	Total [Hz]
Concrete U-early	$(6.81 \pm 0.42) \times 10^{-2}$	
Concrete U-late	$(3.44 \pm 0.25) \times 10^{-2}$	$(1.11 \pm 0.05) \times 10^{-1}$
Concrete Th	$(8.99 \pm 0.59) \times 10^{-3}$	
Shotcrete U-early	$(7.90 \pm 0.14) \times 10^{-1}$	
Shotcrete U-late	$(4.90 \pm 0.10) \times 10^{-1}$	1.40 ± 0.02
Shotcrete Th	$(1.15 \pm 0.02) \times 10^{-2}$	
I-Beams U-early	$(1.47 \pm 0.03) \times 10^{-1}$	
I-Beams U-late	$(6.42 \pm 0.14) \times 10^{-2}$	$(2.13 \pm 0.04) \times 10^{-1}$
I-Beams Th	$(1.42 \pm 0.03) \times 10^{-3}$	
Warm Skin U-early	$(5.91 \pm 0.21) \times 10^{-2}$	
Warm Skin U-late	$(2.56 \pm 0.09) \times 10^{-2}$	$(8.53 \pm 0.23) \times 10^{-2}$
Warm Skin Th	$(5.97 \pm 0.21) \times 10^{-4}$	
Cold Steel U-early	$(1.33 \pm 0.04) \times 10^{-1}$	
Cold Steel U-late	$(6.92 \pm 0.23) \times 10^{-2}$	$(2.03 \pm 0.05) \times 10^{-1}$
Cold Steel Th	$(1.04 \pm 0.03) \times 10^{-3}$	

Overall predicted neutron capture rate of 3.05 ± 0.13 Hz

Neutron capture position

- E.g. for neutron produced in the shotcrete





Geometry updates

- Thickness of some structural layers reduced
- New layers added
- Foam density reduced
- Wood composition updated

Neutron spectra update

- Provided by Vitaly (generated using SOURES4C)