Background in the Dark Matter Experiment DEAP-3600

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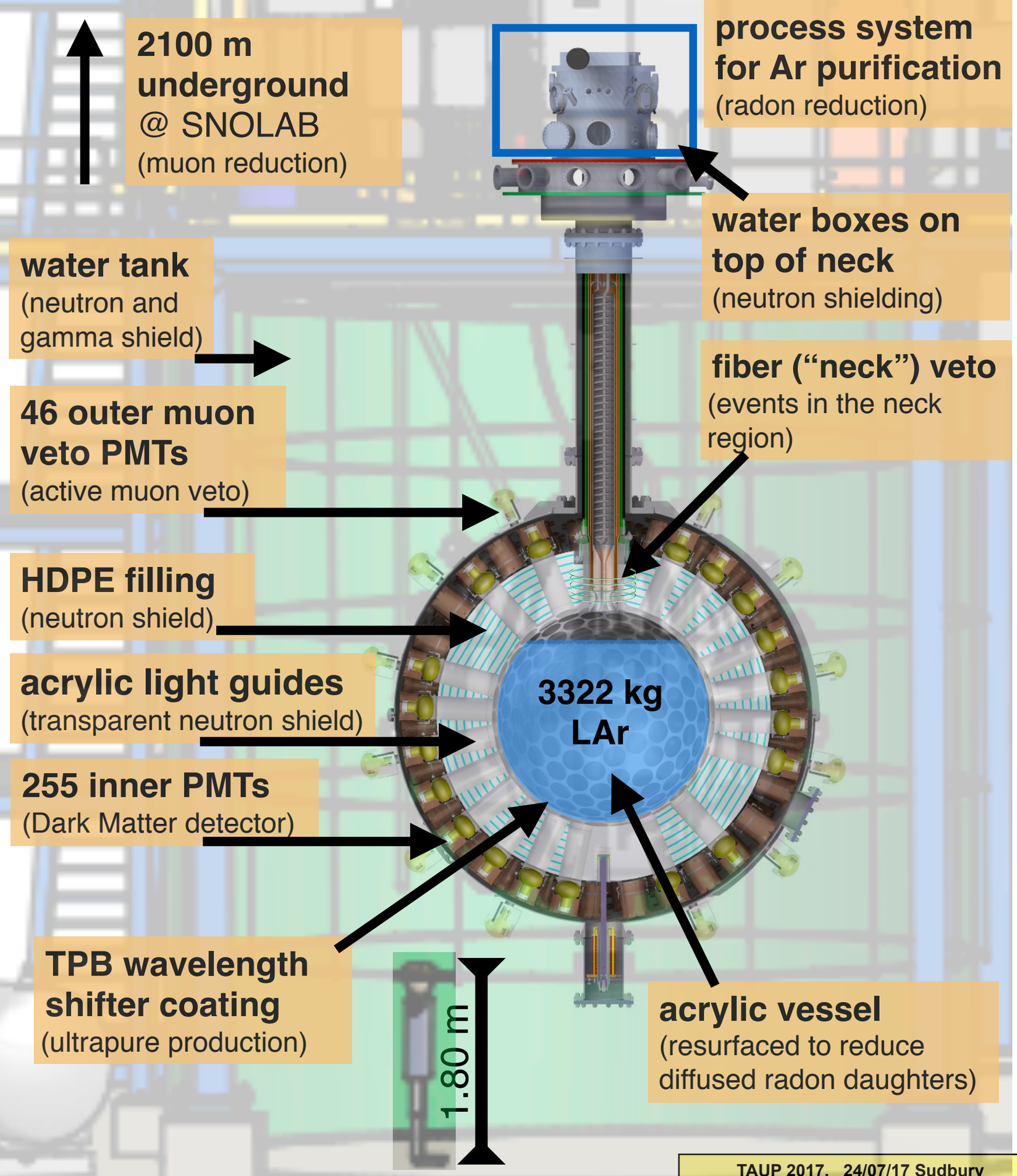
on behalf of the DEAP-3600 Collaboration

Carleton University

TAUP Conference Sudbury 24/07/17

DEAP-3600

M. Boulay
Tuesday 9:30am



- **Single phase** liquid argon (**LAr**) target (new concept)
- Detection of **scintillation** light

- Goal: **< 1 background event** in 3000 kg x yr fiducial exposure

- Sensitivity for spin-independent WIMP-nucleon cross-selection: **10^{-46} cm^2 (@100 GeV)**

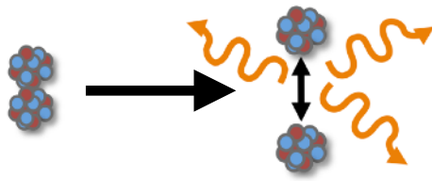
Hardware design concepts for background mitigation:

- Deep underground
- Active muon veto
- Onion-layer passive shielding
- Resurfacing of acrylic vessel to remove diffused radon
- Neutrons from PMTs shielded by long transparent acrylic light guides

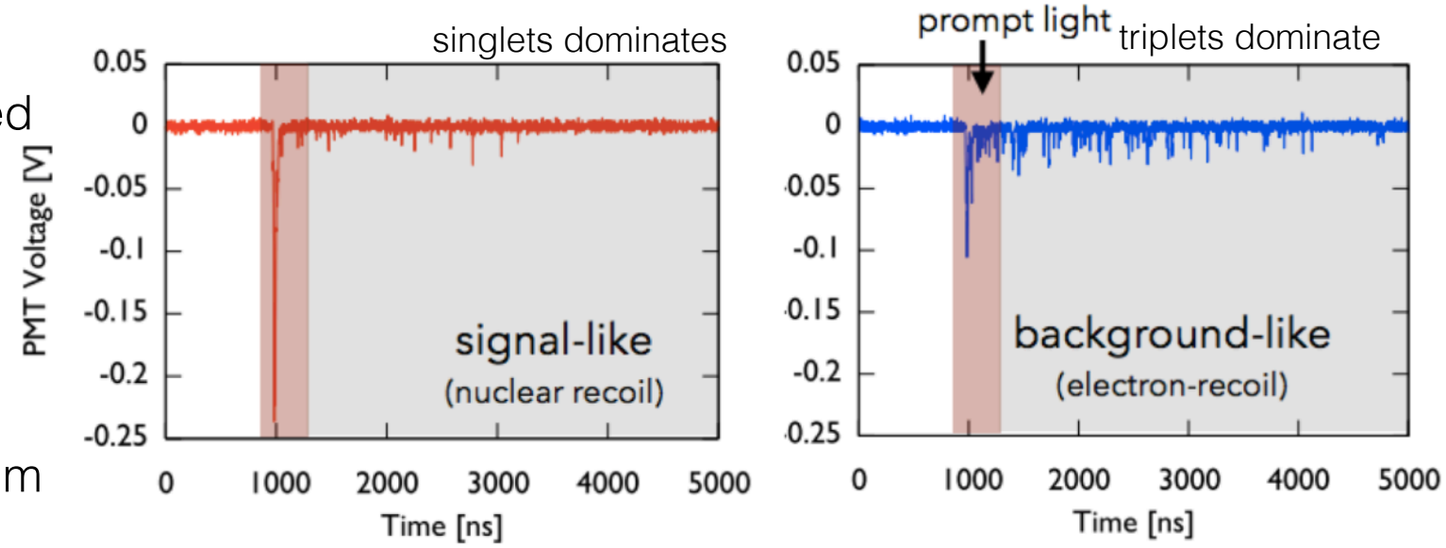
Experimental Signatures

Ar scintillation:

- excimers are created



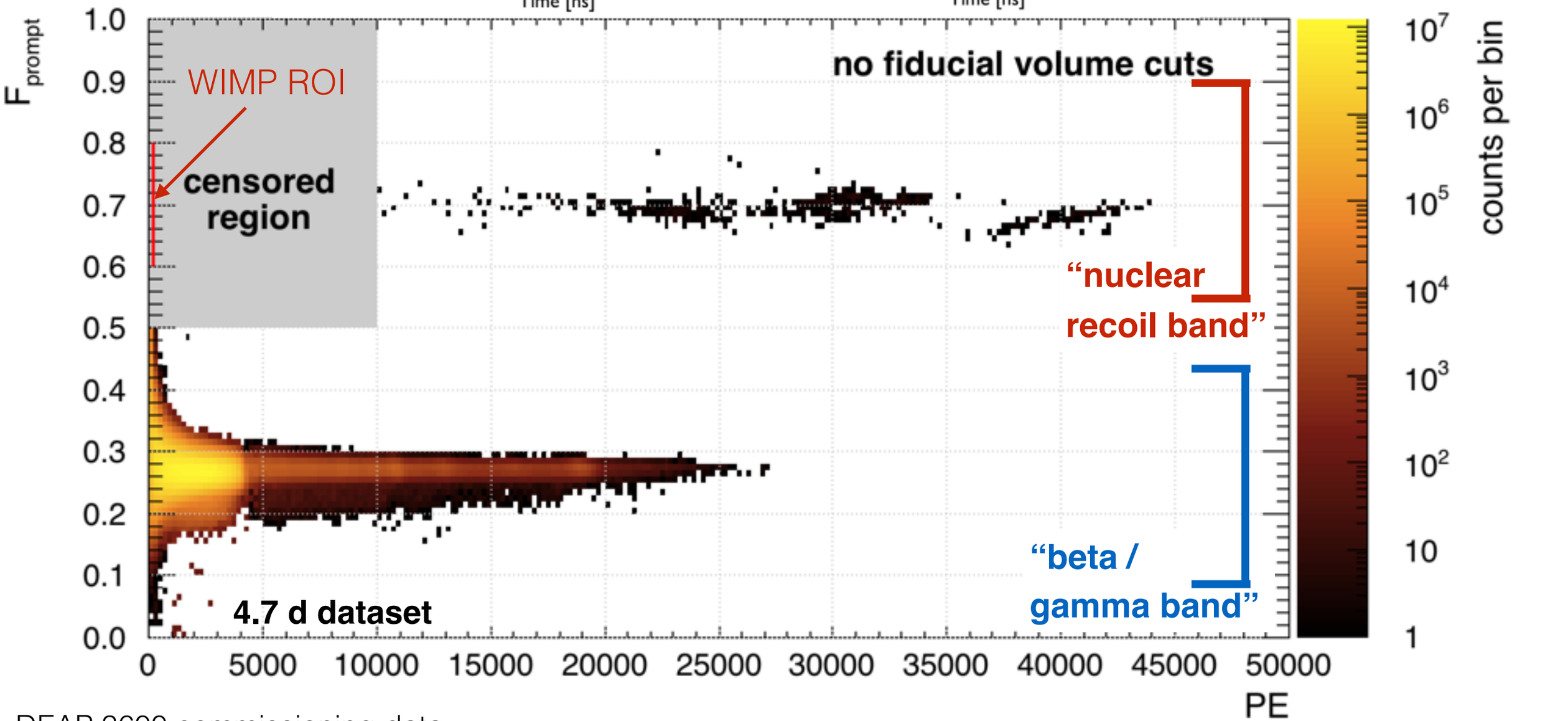
- singlet: 6 ns
- triplet: 1300 ns
- wavelength: 128 nm



Pulse shape discrimination (PSD) parameter:

$$F_{prompt} = \frac{\text{prompt light (150 ns)}}{\text{total light (10000 ns)}}$$

factor 10^{10} separation



DEAP 3600 commissioning data

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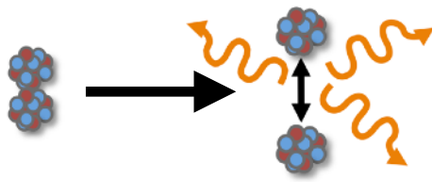

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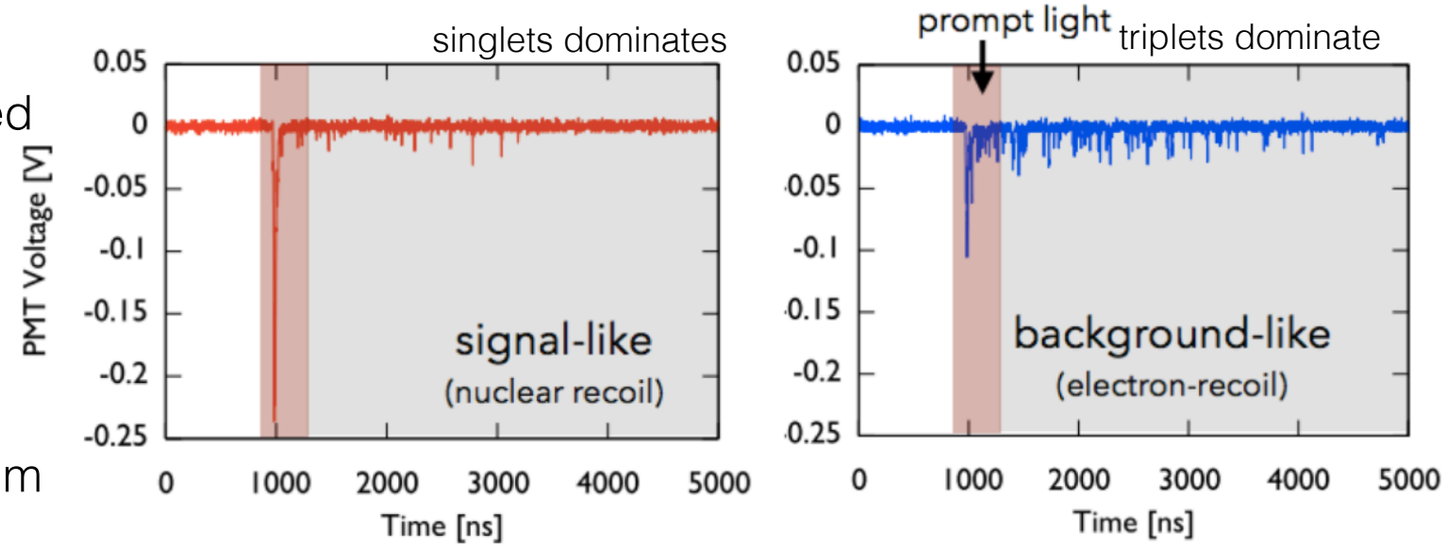

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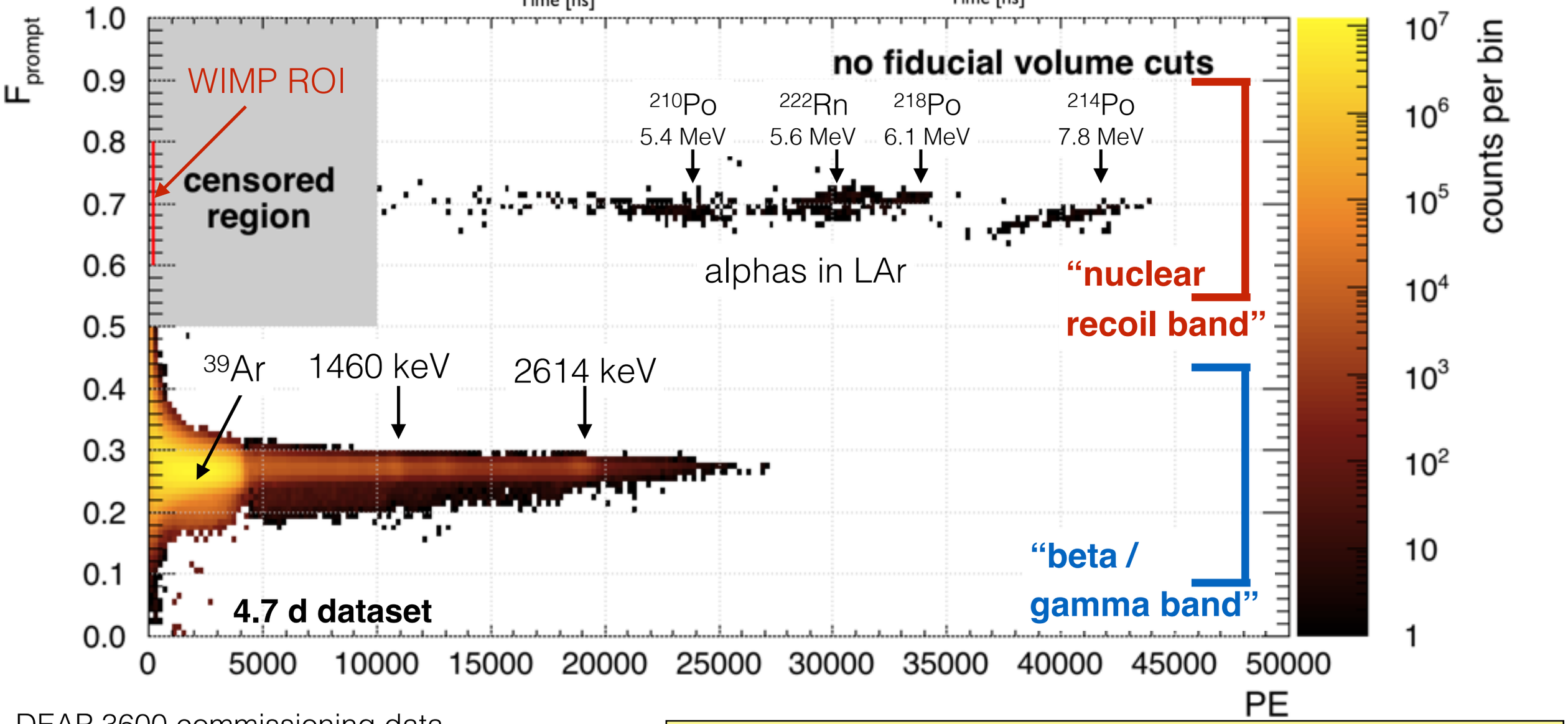


DEAP 3600 commissioning data

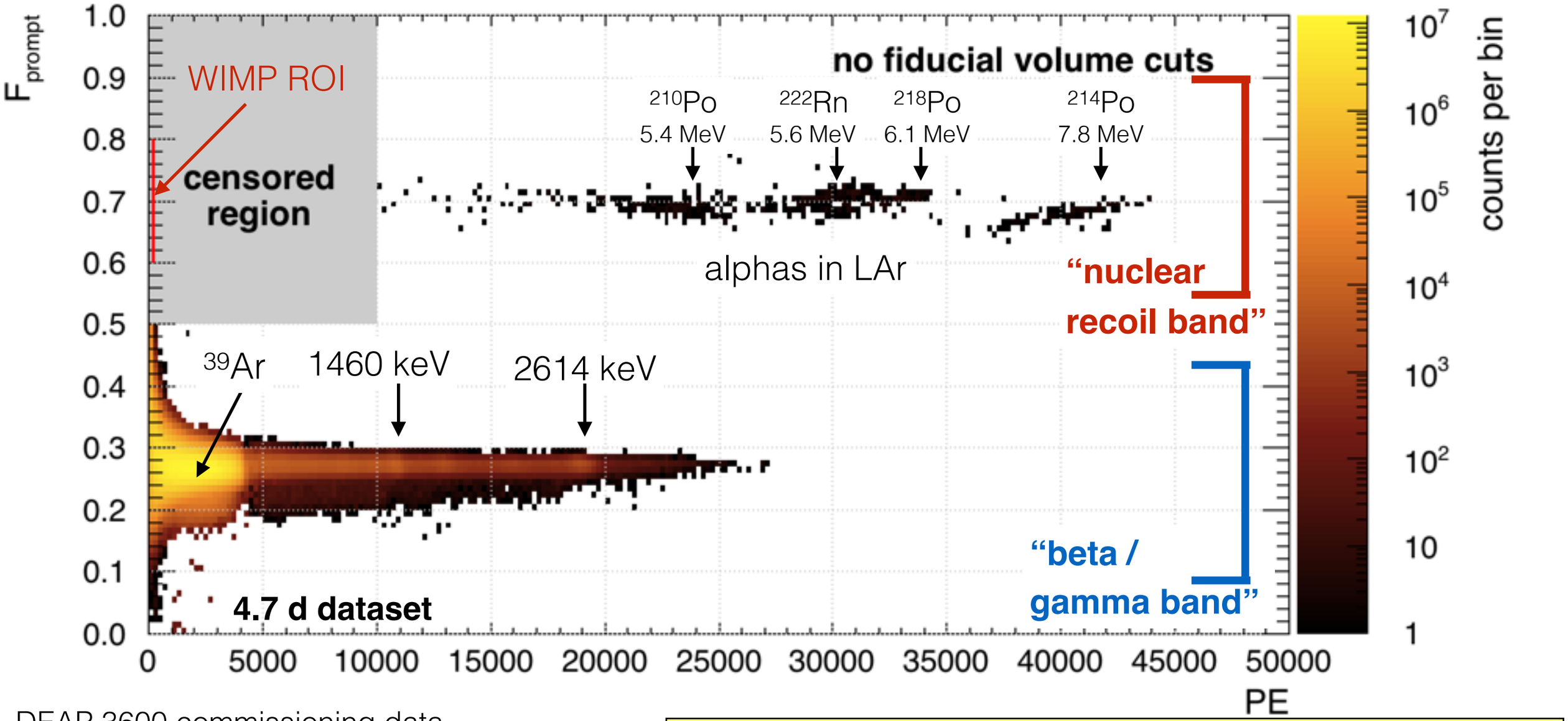
Major Backgrounds in DEAP

Background sources:

- Alphas: Energy degraded or shadowed
- ^{39}Ar: PSD leakage from ER band
- Neutrons: Create Ar NR similar to WIMPs
- Other light sources in the detector

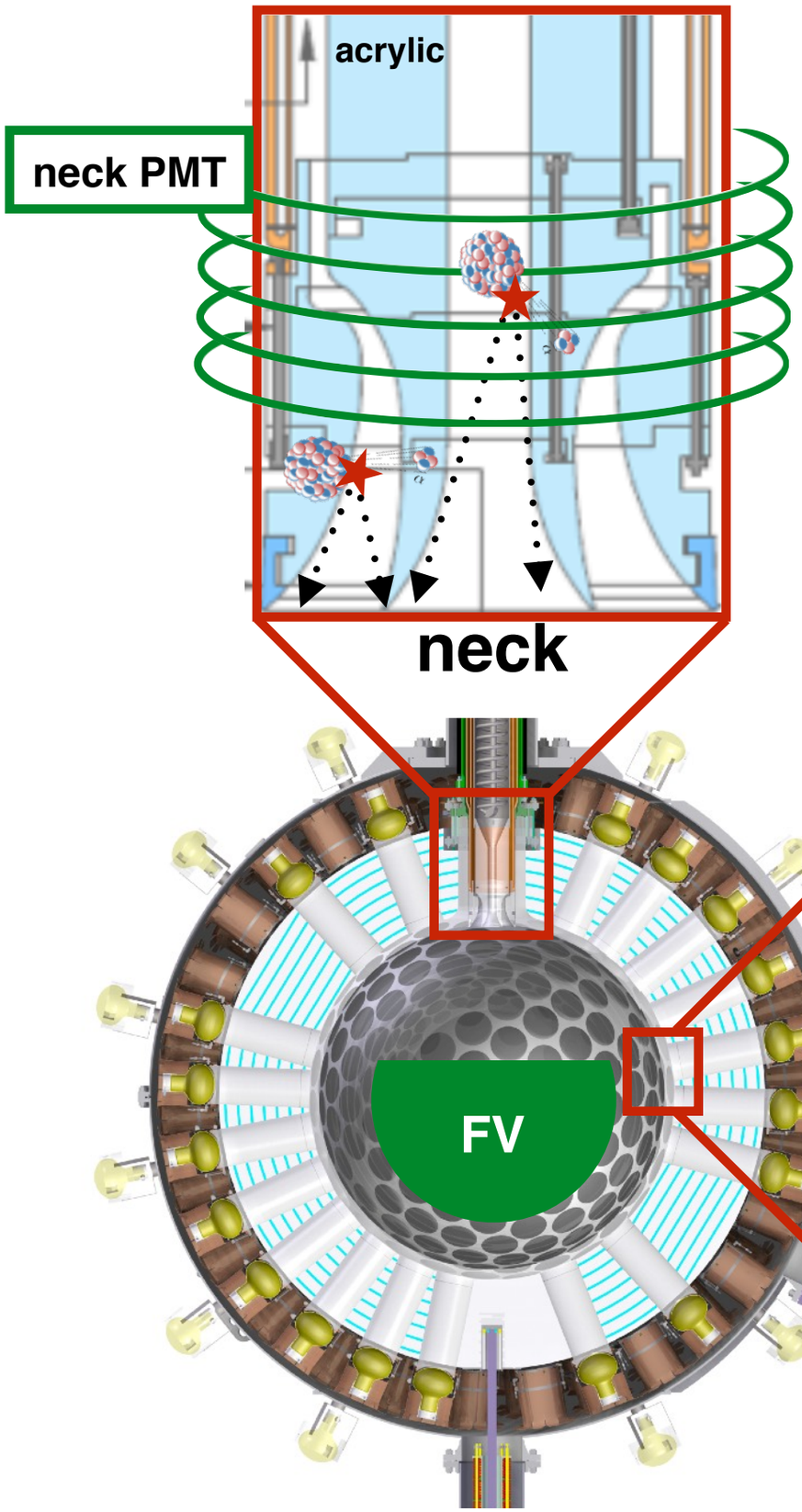
Design goals:

3000 kg x yr exposure	alphas	^{39}Ar	neutrons
events in ROI	< 0.2	< 0.2	< 0.2



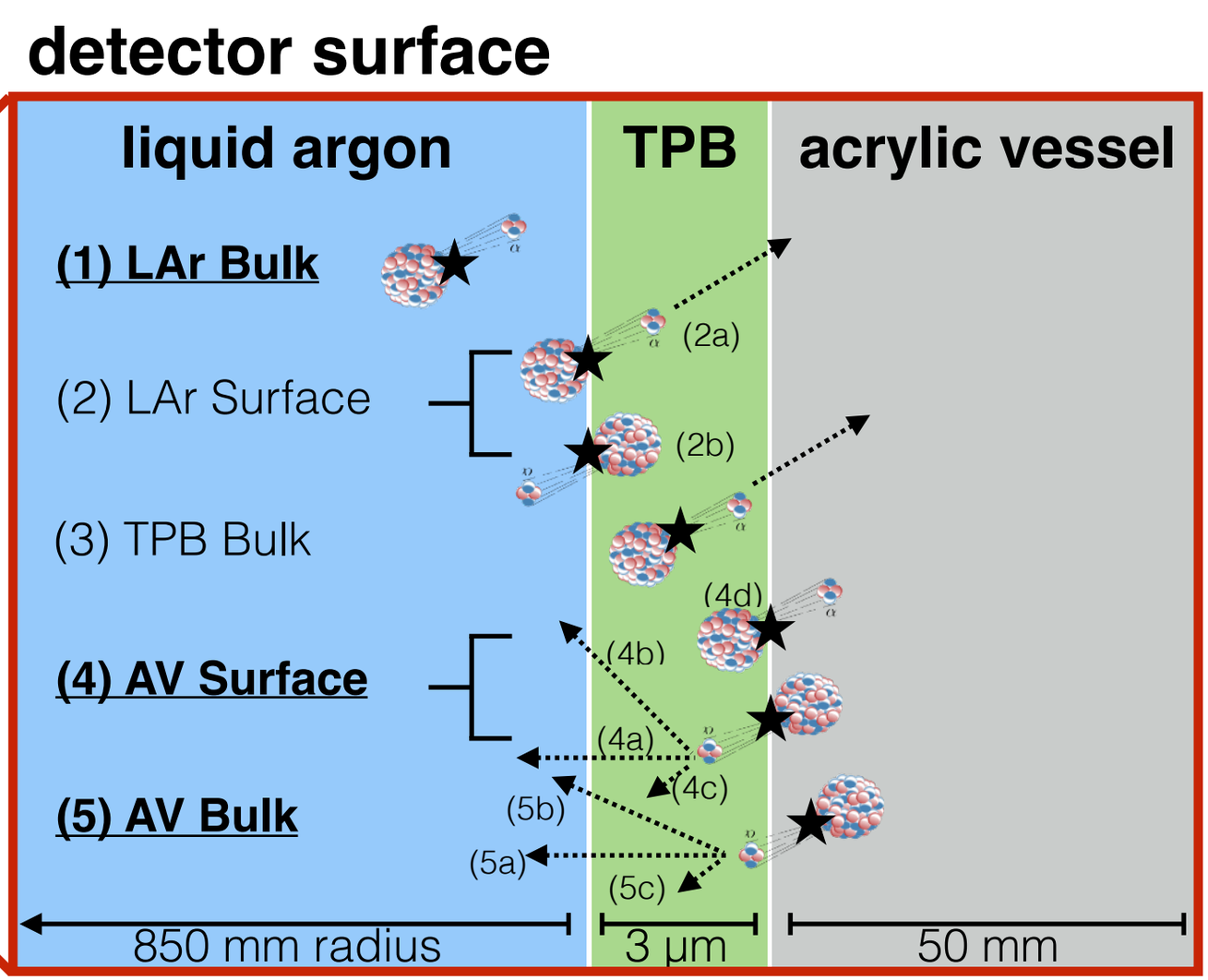
DEAP 3600 commissioning data

Alpha Background Topologies



- Alphas result in a low energy event if:
  - Part of energy is deposited in a dead surface (e.g. acrylic)
  - Energy is deposited in medium with less scintillation (TPB)
  - Scintillation light is lost due to shadowing

- Mitigation in analysis:
  - Fiber ("neck") veto
  - Fiducial volume (FV) cut
  - PMT topology cuts based on charge and timing



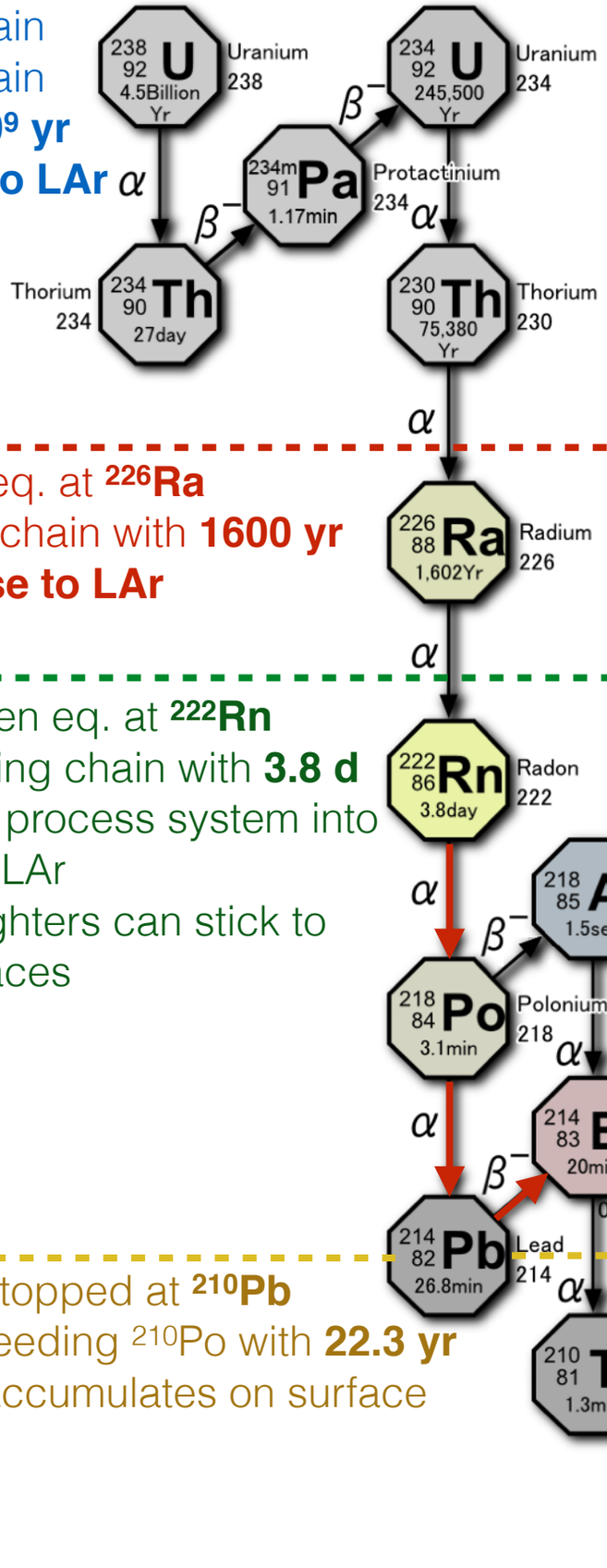
Alphas in the ^{238}U Decay Chain

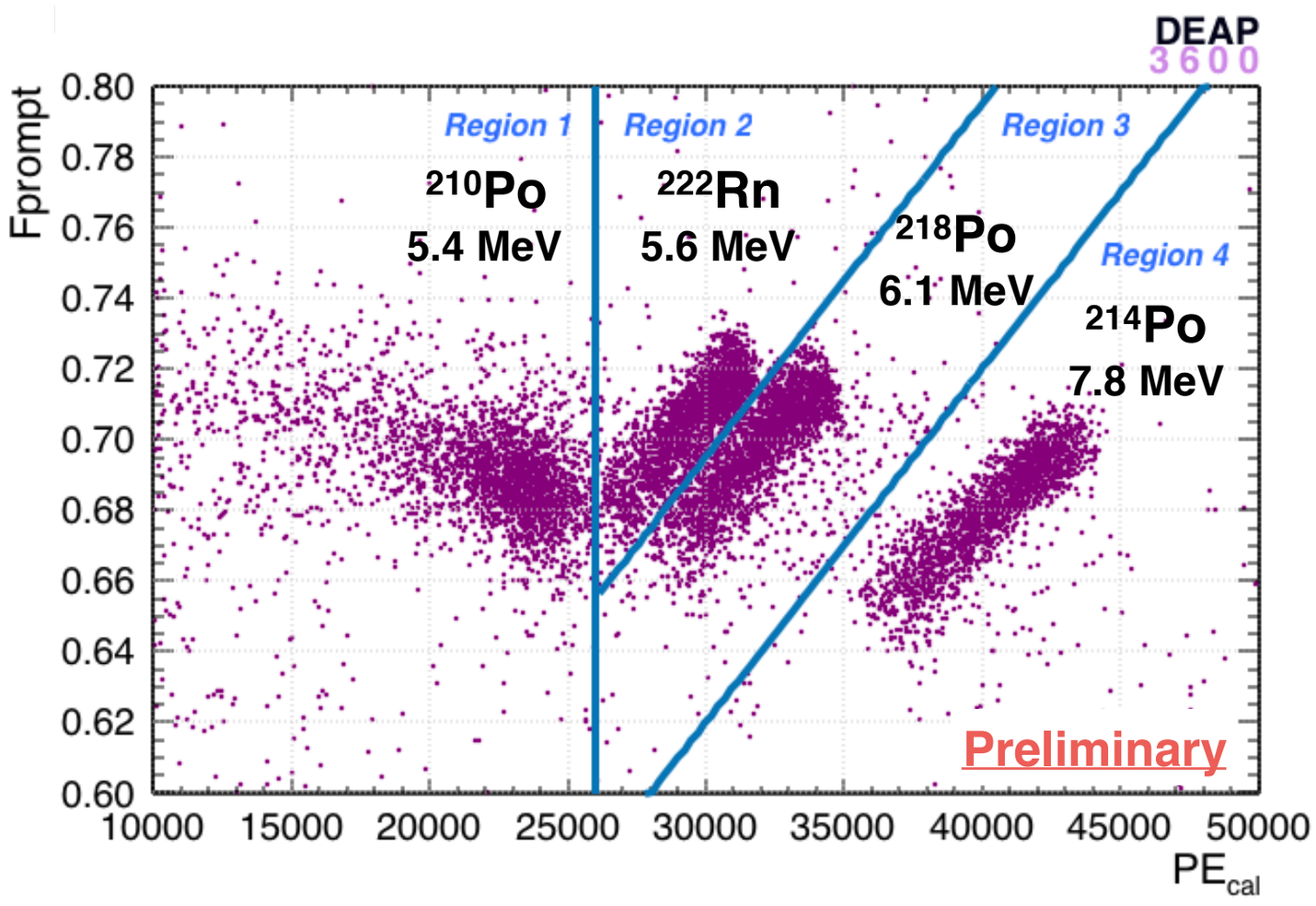
full **^{238}U** chain feeding chain with **4.5×10^9 yr** **not close to LAr**

broken eq. at **^{226}Ra** feeding chain with **1600 yr** **not close to LAr**

broken eq. at **^{222}Rn** feeding chain with **3.8 d** from process system into bulk LAr daughters can stick to surfaces

stopped at **^{210}Pb** feeding ^{210}Po with **22.3 yr** accumulates on surface





- DEAP DAQ is designed for low energy WIMP interactions. Events at alpha energies saturate DAQ

- ^{222}Rn, ^{218}Po, ^{214}Po in LAr bulk:
  - Detector response depends on radius
- ^{210}Po on surface:
  - Equal detector response

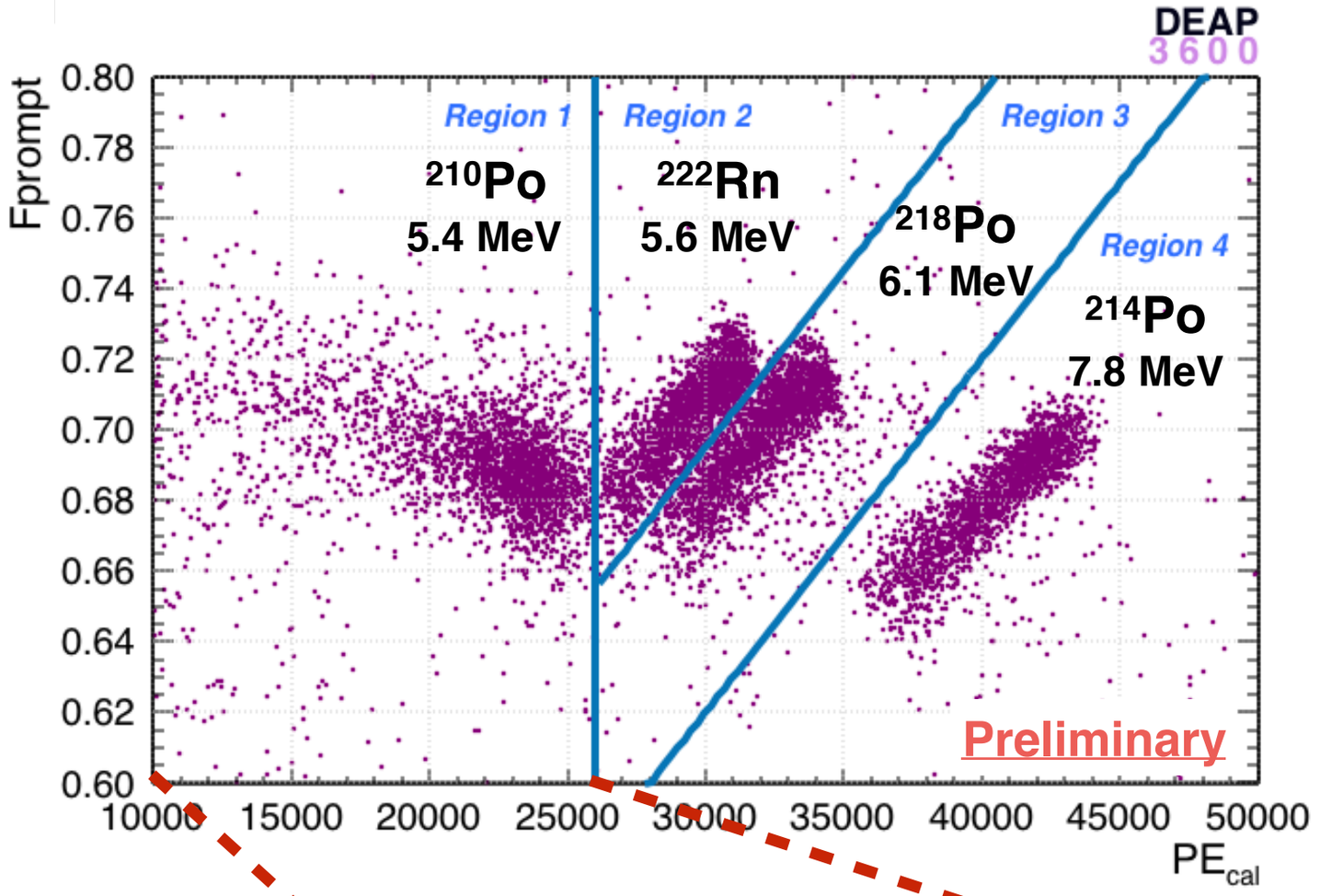
Alpha Background Summary

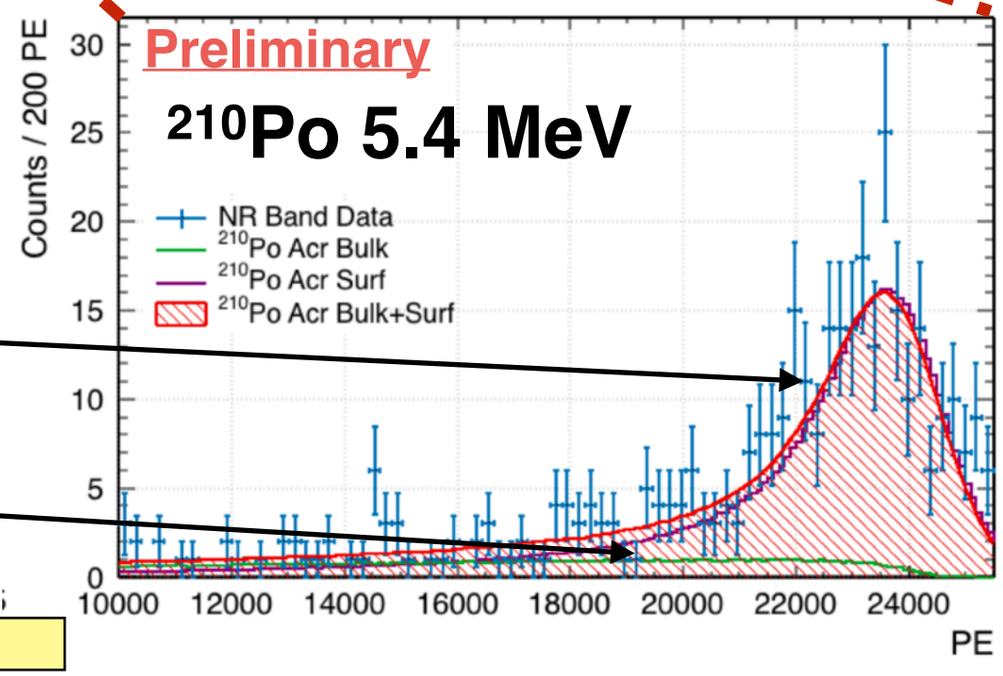
- Measuring the ^{222}Rn content in the bulk LAr shows the very competitive results
- Conclusion: ^{222}Rn induced background within expectations

^{222}Rn in Dark Matter experiments:

Experiment	Activity / rate	Target
DEAP-3600	≈0.2 μBq / kg	LAr
PandaX-II	6.6 μBq / kg	LXe
LUX	66 μHz / kg	LXe
XENON1T	10 μBq / kg	LXe

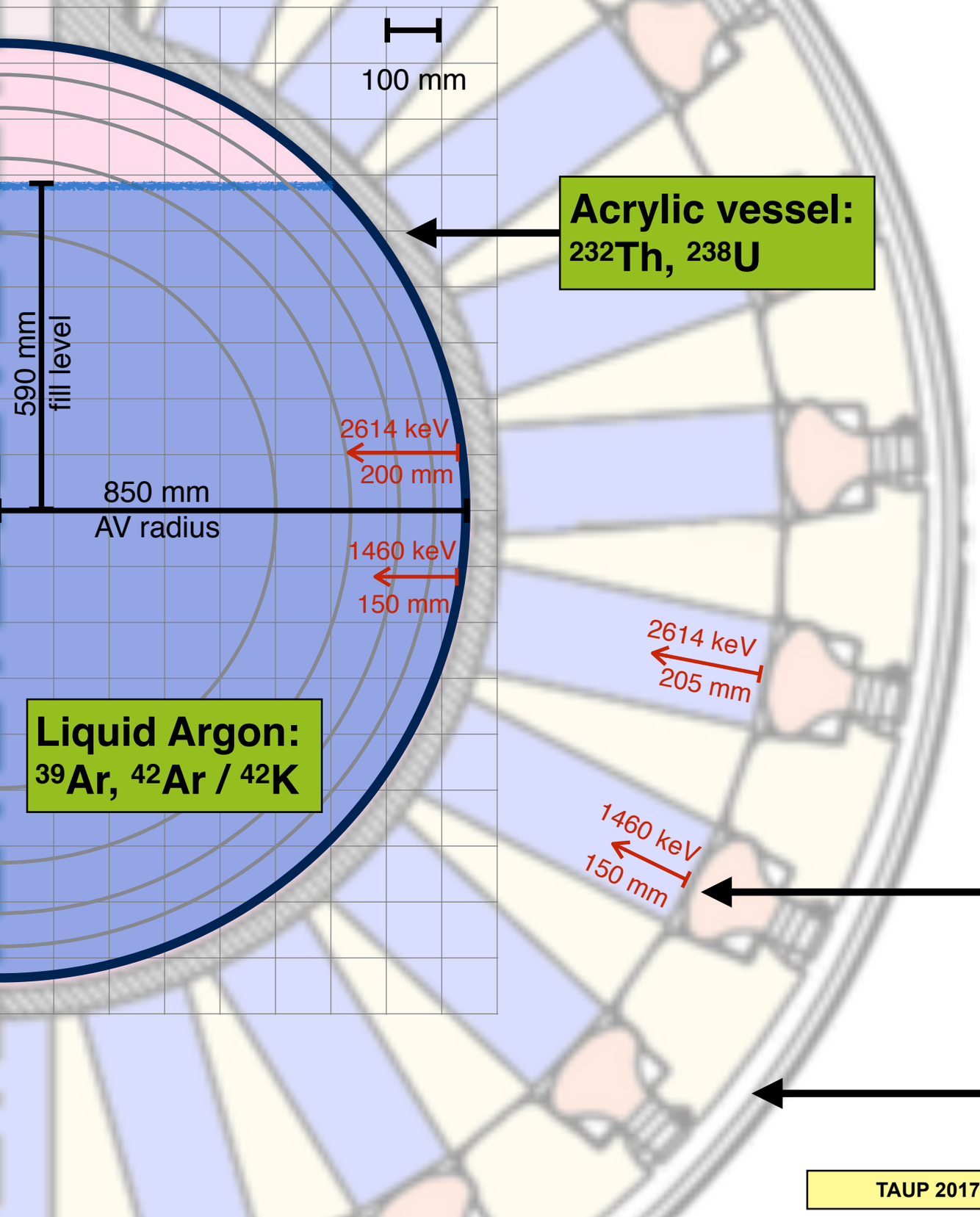
- PandaX-II: PHYSICAL REVIEW D 93, 122009 (2016)
- LUX: Physics Procedia 61 (2015) 658 – 665
- XENON1T: XeSAT 2017 talk [link]





- **Majority (0.2 mBq/m²) of ^{210}Po decays on TPB - acrylic interface**
- **Indication (<2 mBq) of ^{210}Po in 80 μm acrylic bulk (green)**

Gamma and Beta Background

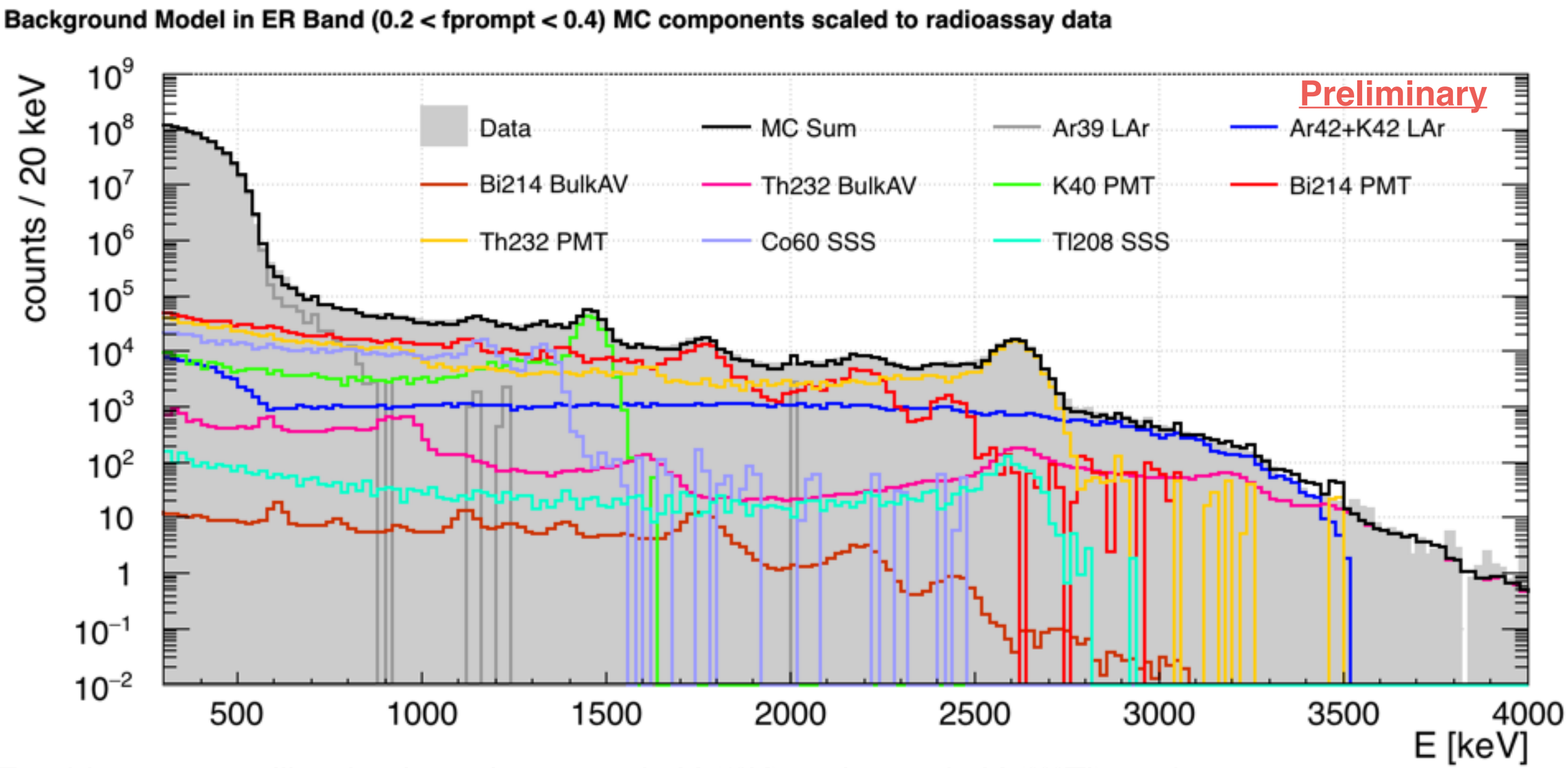


Dominant activities from screening or literature values (approximate)

Isotope	Location	Activity [Bq]	specific activity [mBq/kg]	Concentration [ppb]
^{39}Ar	LAr	3300	1010	
^{232}Th	PMT glass	26	139	34
^{238}U	PMT glass	169	921	75
^{40}K	PMT glass	100	546	18

simulated background components

Gamma and Beta Background Model



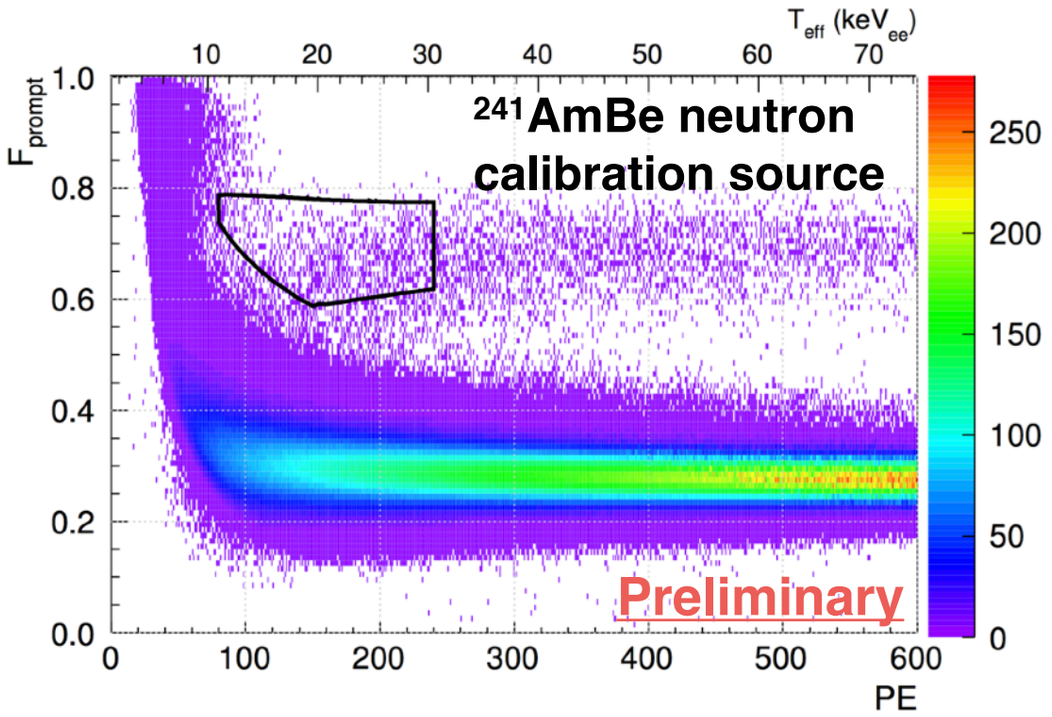
- Empiric energy calibration based on 1460 keV (^{40}K) and 2614 keV (^{208}Tl) peak
- Scaling of MC simulations to known screening / literature values (this is not a fit)
- Low energy region (< 0.5 MeV) dominated by ^{39}Ar
- Mid energy region (0.5 - 2.6 MeV) dominated by gammas from outside components (mainly PMT glass)
- High energy region (> 2.6 MeV) dominated by ^{42}K and by close ^{208}Tl sources

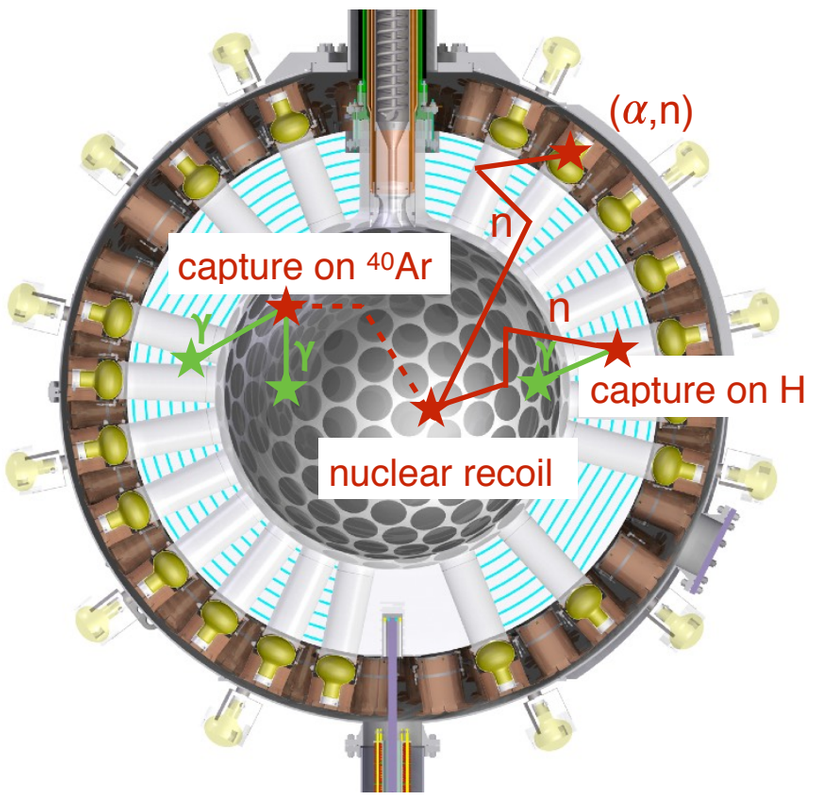
- **Gamma line measurements can be used to constrain (α,n) neutron production within a factor of 2**

Neutron Background

- Neutrons produced by
  - (α,n) reactions in close and far material
  - fission
  - muon induced

- Extensive neutron MC campaign using radio-purity assays and (α,n) yields from SOURCES-4C
  - Dominant source is (α,n) in PMT glass (≈70%)
  - Well constrained from **γ**-background and consistent with target values





Data driven limit on neutron interactions:

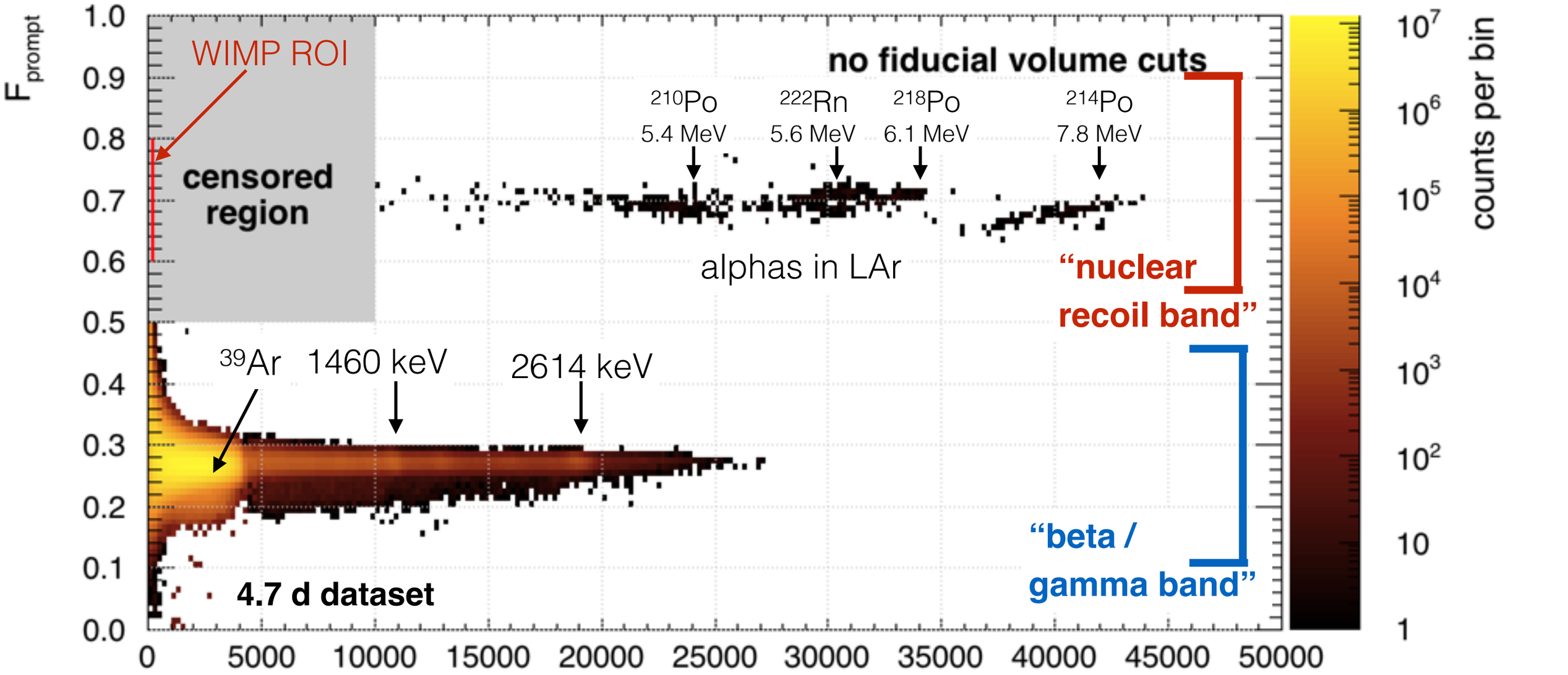
- **Idea:** Eventually all neutrons capture and leave gamma signature
  - 2.2 MeV **γ** form ^{1}H in acrylic
  - 6.1 MeV **γ**-cascade from ^{40}Ar in LAr
  - Search for NR - **γ** coincidences
- **Preliminary result:**
  - No coincidence found above expected random background
  - Limit on neutron interactions consistent with target value

S. Westerdale Tuesday 5pm

Conclusion

- DEAP-3600 design goal is: < 1 bg event in 3000 kg x yr fiducial exposure
- Major expected background components: alphas, neutrons, ^{39}Ar
  - High energy alphas well understood
  - Neutron background constrained with data
  - Electronic recoil background well understood
- Other potential background sources under investigation
- Detailed background model is being constructed

1st DEAP-3600 Results
Tuesday 25/07/17
9:30 am



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