Neutrons and non-Argon materials

A fast study of the possible effect of the detector materials
in the capture distributions from the pulsed neutron source

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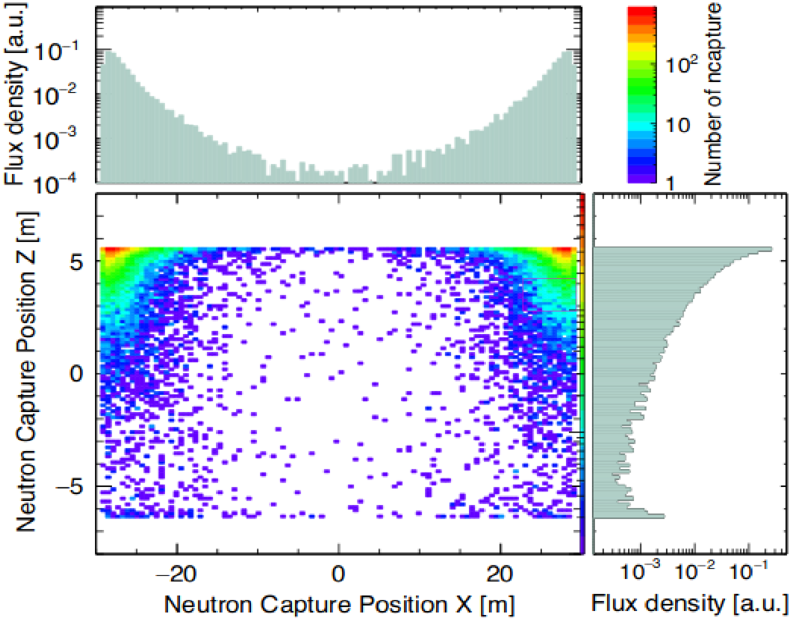
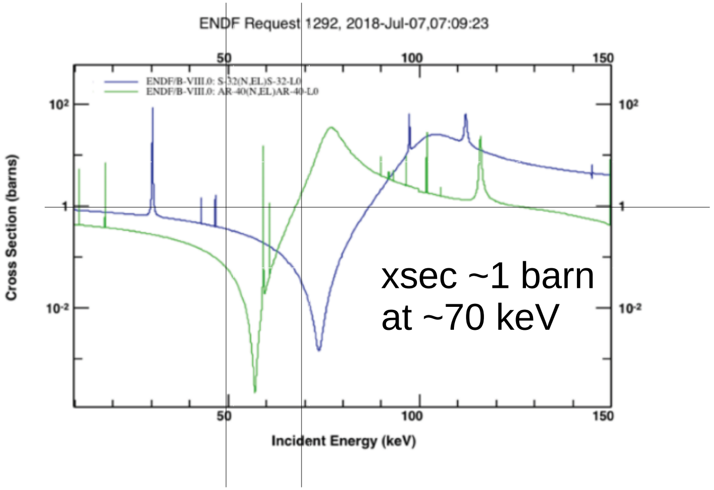
Calibration Task Force, May 2019

neutrons from the PNS

Jingbo’s simulations
(from outside to LAr):





Neutrons enter with 73 keV
Ar anti-resonance at 56 keV

0.1 x flux @ 7 m of LAr
0.01 x flux @ 15 m of LAr
0.001 x flux @ 30 m of LAr

- Neutron sources are inside the manhole-ports
- Two neutron sources located at the corner of the cryostat
- Simulation Notes:
  - Moderator, filter, and absorber are set to vacuum
  - Shoot 73 keV neutrons downward to the cryostat
  - $2x10^5$ primary neutrons
- Number of captured neutrons inside liquid argon TPC: $2.7x10^4$
- Neutron capture distribution is near uniform. Need to run the source at high power

neutrons from the PNS

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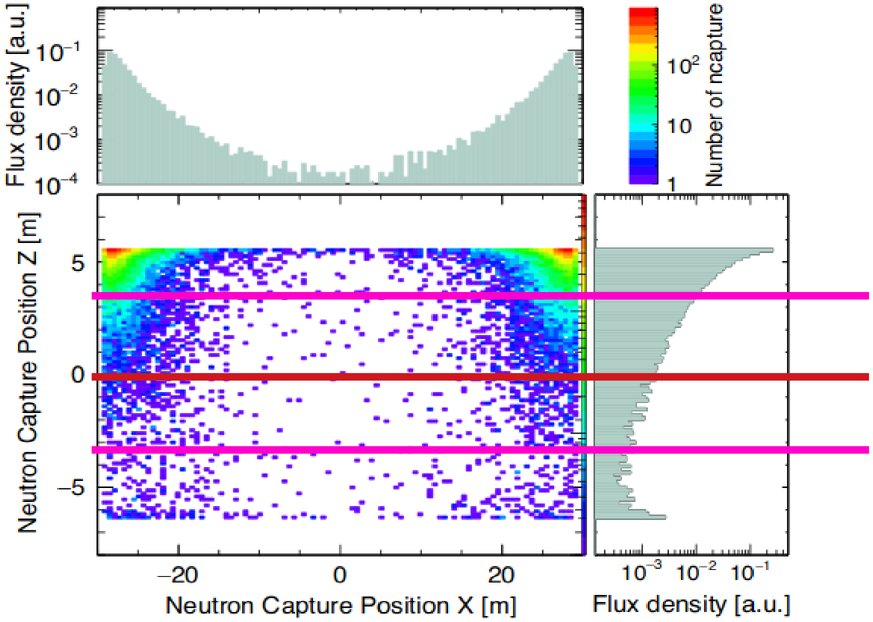
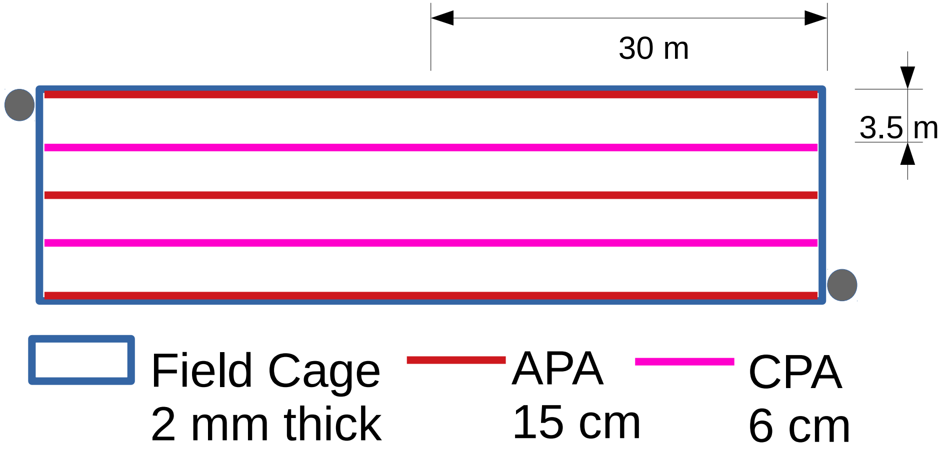
(from outside to LAr):

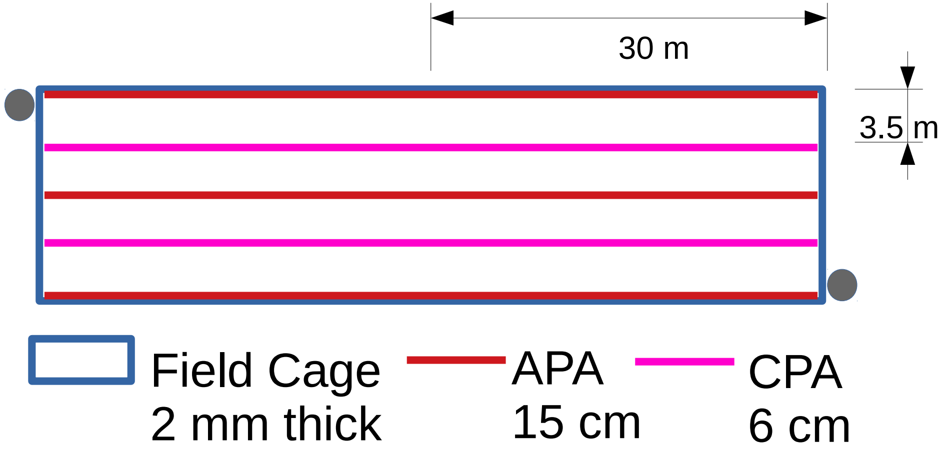




Captures of ~10% in other materials (cm in Y)
almost negligible, but may affect specific positions

0.1 x flux @ 7 m of LAr
0.01 x flux @ 15 m of LAr
0.001 x flux @ 30 m of LAr
seen along the Z-axis, without possible barriers in Y

entering the field cage

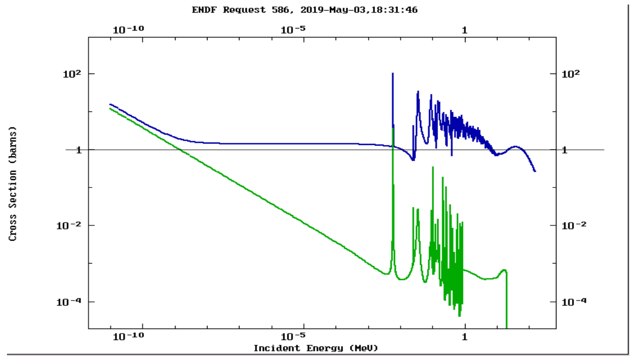


Neutrons must enter the Field Cage crossing at least 2 mm Aluminium

Xsec (capture) = 0.231 barn
Xsec (reson.) = 0.135 barn @ low energy / 0.438 @ high energy
Xsec (elastic) = 1.413 barn (thermal) / 5.385 barn @high energy

6% interact in 2 mm; 25% in 1 cm: half of those scatter out??

In the relevant initial energy range, the elastic cross-section goes up

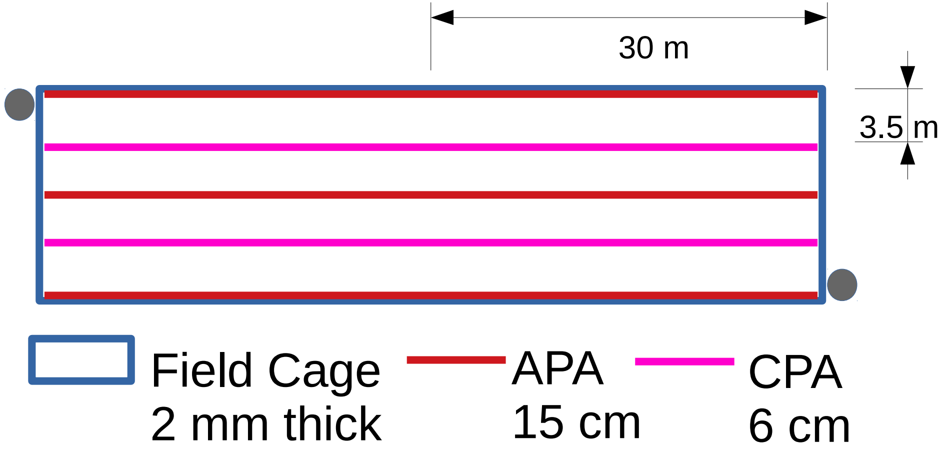


E (keV)	TOT(barn)	CAPT(barn)
0.5 - 1.0	1.349	1.985e-3
1.0 - 100.0	5.385	4.376e-3

How many neutrons do reach the corners of the detector?
a simple composition, easy to simulate the exact effect...

inside the field cage

Cross 1 CPA to reach centre of the detector
Cross 2 x CPA to reach opposite corners
Cross 1 APA for some of the positions



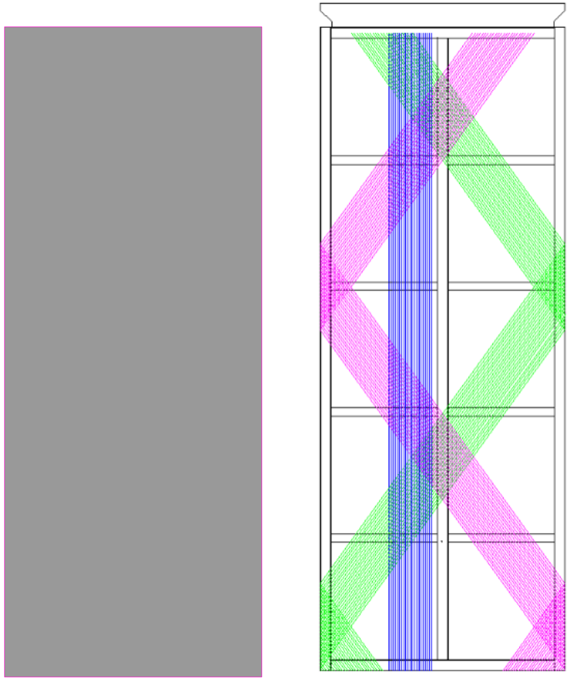


Photo Detectors
installed in APAs
(6 mm of plastic)

APA: 2 x 76 mm of Stainless Steal, in 18% of the area
Wires: 2 x 3 x 0.15 mm of CuBe, in 20% of the area

CPA: 2 x 30 mm of FR4 (and Kapton film) in all area
Some amount of copper (same as APA?)

Total amount of matter distributed over full area,
and ignoring other (mostly more external) components:
effectively, 6 cm thick CPA and 3 cm thick APA

neutrons crossing an APA

Distributing APA matter over all the area; may instead expect small “APA shadows”?

Neutrons may cross the APA, with already decreased energy

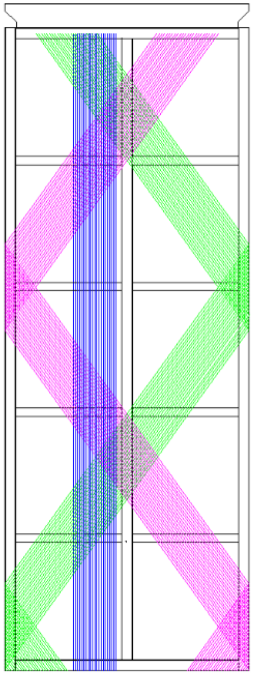
APA Stainless Steal frames

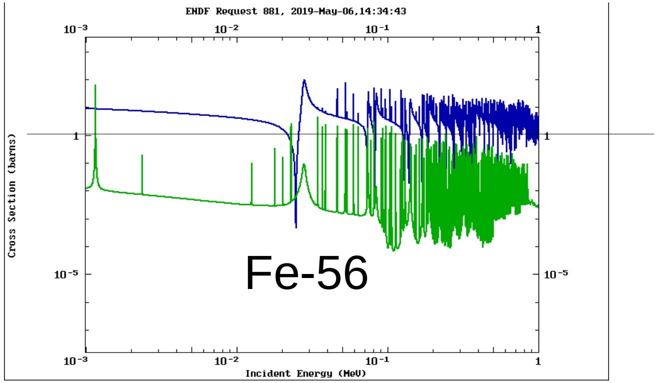
0.9 Fe + 0.1 Cr
8% of low energy neutrons
can capture in 0.27 cm
[x 5 in length => 35% effect]

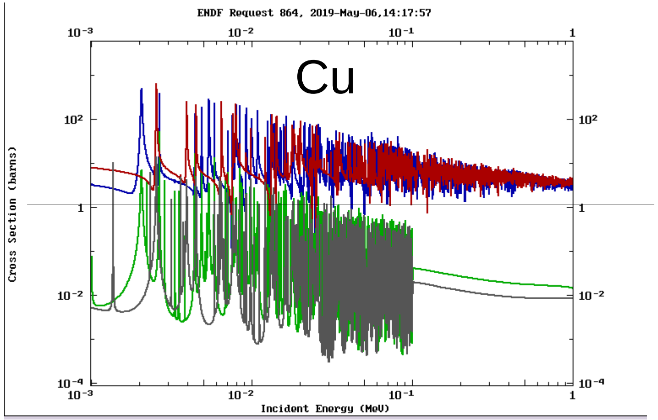
At relevant high energy,
~ 50% have elastic scatter

APA Wires CuBe (98% Cu)
< 1% capture, ~5% elastic in 0.01 cm

==> Net effect of APA ~10%







neutrons crossing the APA

Distributing APA matter over all the area; may instead expect small “APA shadows”?

Neutrons may cross the APA, with already decreased energy

Photon Detectors
neutron capture on 0.6 cm plastic is residual (even with up to 50% of hydrogen)

But scattering is important!

* exact composition of PD?

* effect of neutrons on PD?

* effect on T0 determination?

Scattering with high A materials is not a big problem
(ex: up to ~5 scatters in Ar to leave anti-resonance)

Scattering with low A materials reduce neutron energy fast
(ex: on average half the energy lost per scatter on proton!)

Hydrogen content of each material is relevant parameter!

Expect accumulation of captures near Photon Detectors

neutrons crossing a CPA

CPA materials do cover all the area; may block neutrons from some regions?
Neutrons may cross up to 2 CPA, with high and already decreased energy
At high angles to reach the centre of the detector

6 cm of complex material (FR4)

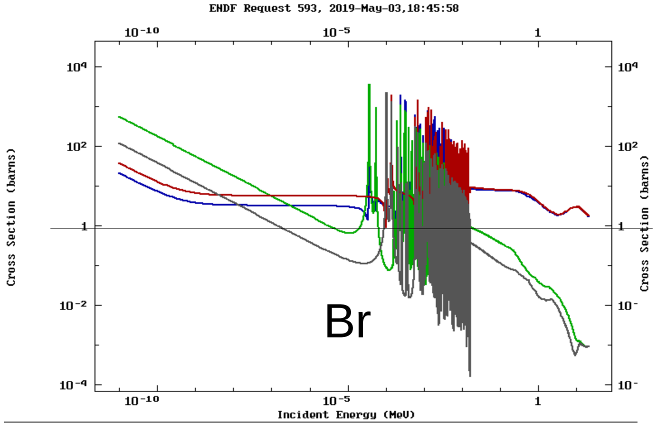
70% SiO_2 + 30% Epoxy ($C_{19}H_{19}O_3$)?

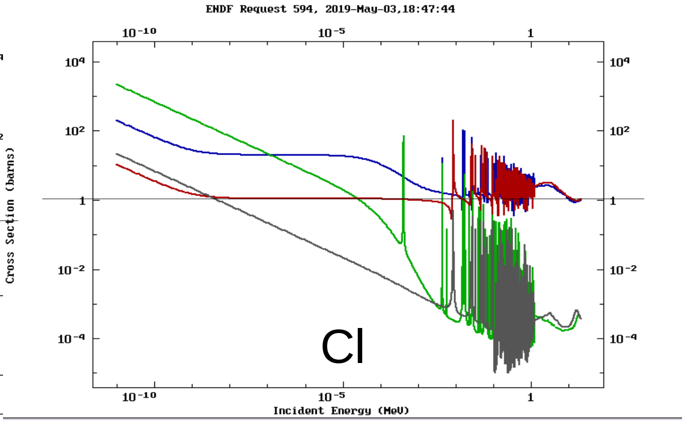
Extra components negligible?

Cu - 0.15 mm?

Kapton ($C_{22}H_{14}O_7N_2$) - film of 0.6 cm?

Br / Cl (with limits) < 1% !!





Br has high capture cross-section at high energy

halogen free FR4 at proto-DUNE
(<900 ppm Br/Cl; <1500 ppm Br+Cl)

Br / Cl (with limits) < 1%
(could easily go to 50%, new capture signals?)

neutrons crossing a CPA

CPA materials do cover all the area; may block neutrons from some regions?
Neutrons may cross up to 2 CPA, with high and already decreased energy
At relatively high angles to reach the centre of the detector

6 cm of complex material (FR4)

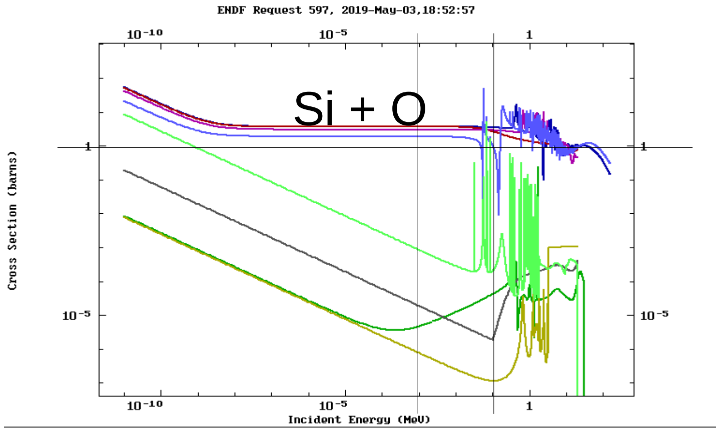
70% SiO_2 + 30% Epoxy ($C_{19}H_{19}O_3$)?

~7.5% capture (5% SiO_2 + 2.5% Epoxy)

Net effect on CPA ~10% captures [similar to APA]

But around the CPA effect can be much larger!!

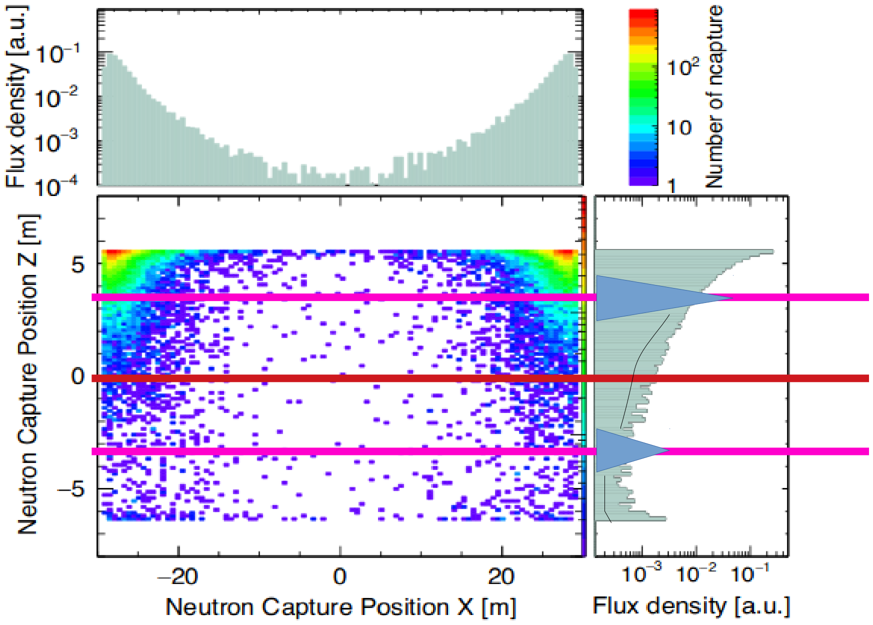
many captured in LAr around the CPA?
fluxes can be decreased by 50% in y-axis?

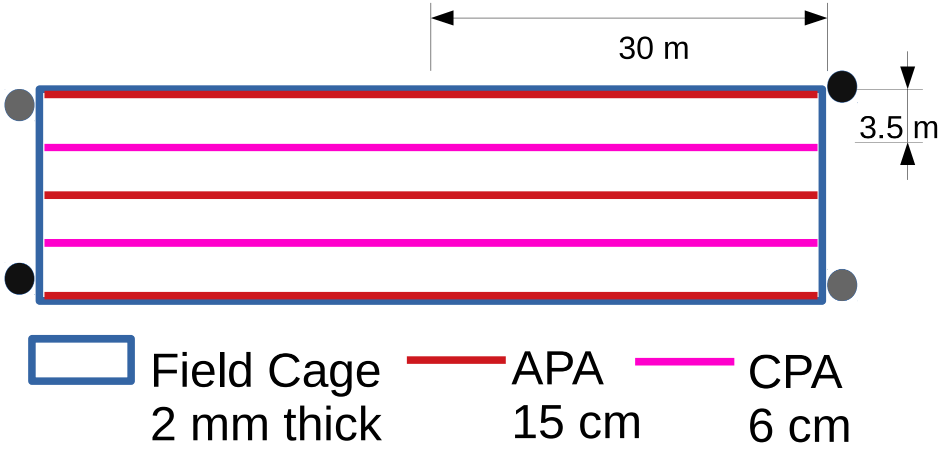


SiO_2 absorption ~ 5%
SiO_2 scattering ~ 33%
Scattering in H ~ 50% ?

neutrons from the PNS

Jingbo's simulations
(from outside to LAr):





Distribution may be quite different in Y!

1) Redo calculations with correct H contents
2) Coverage at opposite corners and centre

If neutron captures when crossing CPA are significant
we may need extra PNS on 2 other corners ●

Captures close to PD may affect T0 analysis?

Neutrons and non-Argon materials

The “non-transparency” of APA and CPA due to direct neutron capture is small

~10%, negligible compared to spreading over many meters of Argon

But the capture population may be concentrated in specific volumes

- expect extra captures close to CPA (and PD)

- reduce coverage of detector corners and centre

Some materials should be avoided where possible (halogen free FR4)

Check composition of materials and namely exact Hydrogen content

Very preliminary worries: will need more precise calculations with corrected inputs