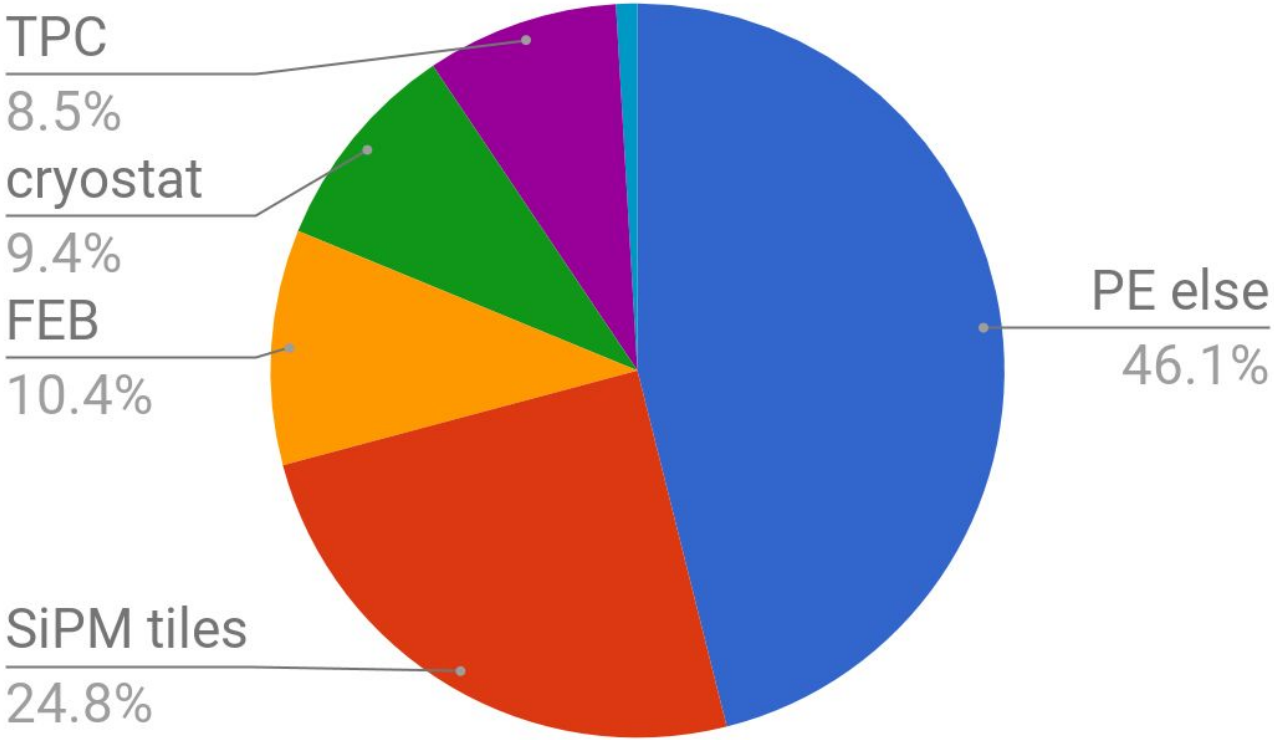
# n-budget status

V. Pesudo
CIEMAT
on behalf of the Materials WG
DarkSide General Meeting, L'Aquila March 19

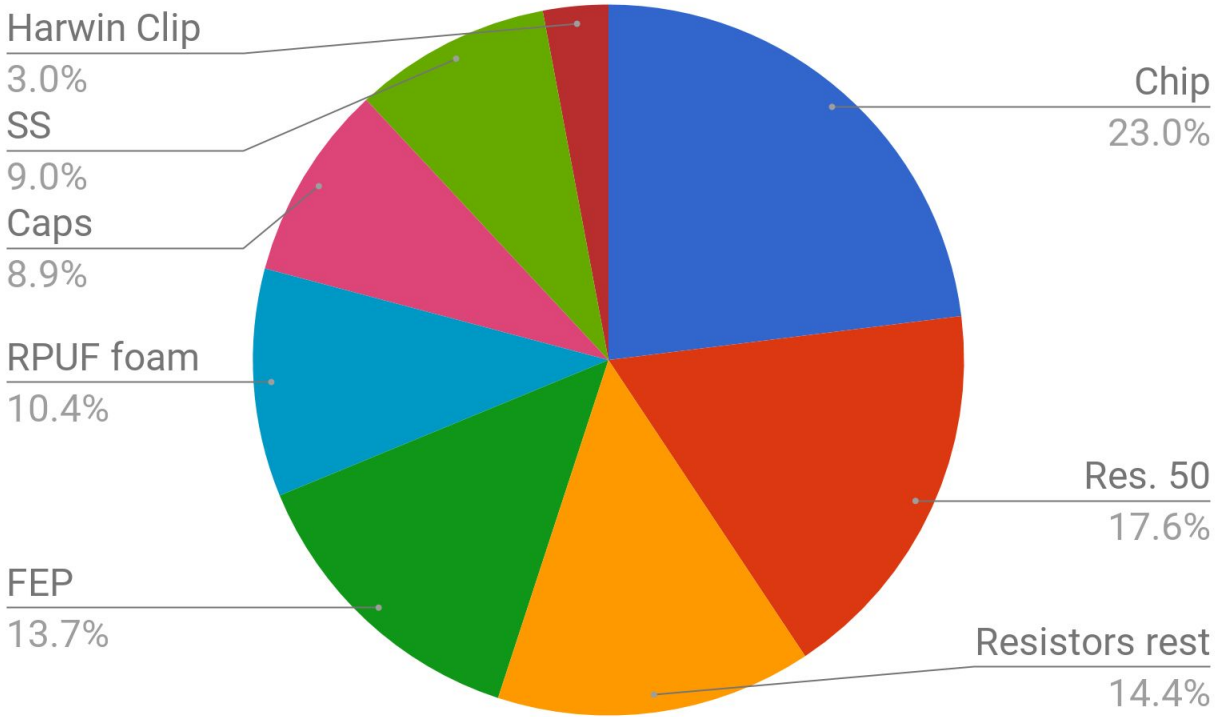
Quick numbers: total number of expected neutrons after cuts with current status:
**0.49 n in 100 t y after cuts.**

| | n after cuts |
|---|---|
| PE else | 1.8E-1 |
| SiPM tiles | 9.7E-2 |
| FEB | 4.1E-2 |
| cryostat | 3.7E-2 |
| TPC | 3.3E-2 |
| Veto | 3.7E-3 |



# The bad guys: they sum 0.39 n after cuts, 81% of current budget.

| | n after cuts |
|---|---|
| Chip | 8.0E-2 |
| Res. 50 MOhm | 6.1E-2 |
| Resistors rest | 5.0E-2 |
| FEP | 4.8E-2 |
| LED | 4.7E-2 |
| RPUF foam | 3.6E-2 |
| Caps | 3.1E-2 |
| SS | 3.0E-2 |
| Harwin Clip | 1.0E-2 |



# Cryostat

Limiting factor is the PU foam.

Inefficiency of neutrons from the cryostat is an upper limit (6.5  $10^{-10}$).

High statistics simulations ongoing.

Assay request of new material attended (to be sent to Temple).

| Component | position or | | material | [kg] | n in 100 t yr | n bg / (100 t yr) |
|---|---|---|---|---|---|---|
| | #/PDM | \| mg/u | | [mg/PDM] | | |
| **Cryostat** | | | | | | |
| Stainless steel | cryostat | | Stainless steel MSS0364 DUNE | 27104 | 92567 | 6.0E-5 |
| PU foam | cryostat | | RPUF insulating foam | 25344 | 55442961 | 3.6E-2 |
| plywood | cryostat | | Plywood | 2185.92 | 980393 | 6.4E-4 |

# Conclusions

**Dominance (urgent stuff?)** Not a priority at the moment.

**Everything assayed?** yes

**Needed more assays (complete chain or enhance sensitivity)?** more assays requested by CERN people. New batch?

**MC status:** MC input needed to validate inefficiency (critical for PU results).

# Veto

Everything based on databases, no assay of veto material performed by ourselves so far.

Acrylic in the order of 10 ppts (JUNO) can be provided by the company and is not an issue in terms of n production.

Gd doping candidates must be evaluated the sooner the better.

It would be good to understand the differences between DEAP’s production and this one and try to go down to ppt level

# Veto

| Component | position or | | material | [kg] | n in 100 t yr | n bg / (100 t yr) |
|---|---|---|---|---|---|---|
| | #/PDM | \| mg/u | | [mg/PDM] | | |
| **VETO** | | | | | | |
| Gd sulfide | Veto PS (5 cm) | | Gd2(SO4)3 | 458.64 | 186 | 4.3E-4 |
| Acrylic bulk shell | Veto PS (5 cm) | | Acrylic 10 ppt | 11700 | 379 | 8.7E-4 |
| Acrylic bulk panels | Veto PS (5 cm) | | Acrylic 10 ppt | 1120 | 36 | 8.3E-5 |
| Acrylic bulk | Veto PS (5 cm) | | Gd2(SO4)3 on Acrylic | 458.64 | 631 | 1.5E-3 |
| Reflector | Veto PS (5 cm) | | Vikuiti | 100 | 60 | 1.4E-4 |
| Veto support structure | Veto PS (5 cm) | | SS DS50 | 1170 | 302 | 6.9E-4 |
| Faraday cage | Veto PS (5 cm) | | Cu | 1071 | 6 | 1.4E-5 |
| SiPMs (3000) | Veto PS (5 cm) | | | | 1825 | 4.2E-3 |
| SiPM electronics* | Veto PS (5 cm) | | | | 4161 | 9.6E-3 |

# Conclusions

**Dominance (urgent stuff?)** Not a priority at the moment.

**Everything assayed?** Nope. Nothing, actually.

**Needed more assays (complete chain or enhance sensitivity)?** Yes. Gd and Pb-210 contamination of acrylic sample to start with.

**MC status:** Geometry still under discussion, not massive changes expected but needs to be properly simulated.

# TPC

| Component | position or | | material | [kg] | n in 100 t yr | n bg / (100 t yr) |
|---|---|---|---|---|---|---|
| | #/PDM | \| mg/u | | [mg/PDM] | | |
| **TPC** | | | | | | |
| TPC support structure | Steel structure | | SS Proto structure | 1071 | 900 | 3.0E-2 |
| Sh. rings resistors | Reflector | | Field cage resistor 1 GOhm | 0.013 | 3.67 | 1.2E-4 |
| Sh. rings resistors solder | Reflector | | Solder Indalloy 290 | 0.2 | 6.36 | 2.1E-4 |
| Acrylic panels | Reflector | | Acrylic 10 ppt | 700 | 22.67 | 7.5E-4 |
| Acrylic plates | TPC Top/Bottom | | Acrylic 10 ppt | 2000 | 64.77 | 2.1E-3 |
| Vikuiti reflector | Reflector | | Vikuiti | 1.6 | 0.96 | 3.2E-5 |
| Vikuiti reflector | TPC Top/Bottom | | Vikuiti | 8 | 4.79 | 1.6E-4 |
| Conductive polymer | Vessel | | clevios | 1 | 1.70 | 5.6E-5 |

# TPC

Steel: Using DS50’s steel reduction of x3.

Solder mass for resistors considered 200 g. Reasonable?

No surface contamination considered.

As in Veto, a lot of acrylic. Pb-210 in acrylic needs to be taken care of (3 mBq/kg would be nasty).

# Conclusions

**Dominance (urgent stuff?)** Steel.

**Everything assayed?** Only clevios (and structure for proto).

**Needed more assays (complete chain or enhance sensitivity)?** Start evaluation of steel? Resistors request this week, HPGe on solder. Reflector?

**MC status:** I think simulations included Cu shaping rings. Have to cross-check if the MC numbers are with the current TPC thickness.

# Fibers

Estimation: 230 um thick fiber (fused silica) + 900 um Peek jacket.

They have not been assayed. Numbers based on scaled up fused silica (x$10^3$); 8 mBq/kg U, 2 mBq/kg Th, 1 Bq/kg $^{210}$Pb.

Peek jacket only ICPMS results. Strong dependence on mid and lower chain.

Assuming 4.5 m on bottom + 6 m along vessel + 4 m to flange.

| Component | position | | material | | n in 100 t yr | n bg / (100 t yr) | | |
|---|---|---|---|---|---|---|---|---|
| CABLES+FIBERS | | 103500 m | | mass | | | | |
| | | g/m | | [kg] | | | mid chain 70m | Pb 1 Bq |
| Opt. Fiber top | TPC top/b | 1.1E-1 | fused silica dirtier | 2.2E+0 | 2.8E+1 | 9.4E-4 | 9.4E-4 | 9.4E-4 |
| O. Fib. jacket top | TPC top/b | 3.2E-1 | peek fiber | 6.4E+0 | 1.1E+1 | 3.7E-4 | 3.0E-3 | 7.6E-3 |
| Opt. Fiber bottom | TPC top/b | 1.1E-1 | fused silica dirtier | 2.2E+0 | 2.8E+1 | 9.4E-4 | 9.4E-4 | 9.4E-4 |
| O. Fib. jacket bottom | TPC top/b | 3.2E-1 | peek fiber | 6.4E+0 | 1.1E+1 | 3.7E-4 | 3.0E-3 | 7.6E-3 |
| Opt. Fiber side (bottom | TPC side | 1.1E-1 | fused silica dirtier | 3.0E+0 | 3.8E+1 | 1.2E-3 | 1.2E-3 | 1.2E-3 |
| O. Fib. jacket side | TPC side | 3.2E-1 | peek fiber | 8.6E+0 | 1.5E+1 | 4.9E-4 | 4.0E-3 | 1.0E-2 |
| Opt. Fiber to flange | Veto PS (5 | 1.1E-1 | fused silica dirtier | 2.0E+0 | 2.5E+1 | 5.8E-5 | 5.8E-5 | 5.8E-5 |
| O. Fib. jacket to flange | Veto PS (5 | 3.2E-1 | peek fiber | 5.7E+0 | 9.8E+0 | 2.3E-5 | 1.8E-4 | 4.7E-4 |
| | | | | | | | 1.00E-02 | 2.60E-02 |

# Conclusions

**Dominance (urgent stuff?)** PEEK (potentially, mid and low chain).

**Everything assayed?** No.

**Needed more assays (complete chain or enhance sensitivity)?** mid and low chain missing for PEEK. Nothing on the fibers, yet.

**MC status:** MC input from SiPMs position, reflector and veto. Needs to be improved.

# Cables

- Pure FEP composition used [C 21.7; F 68.7; O 9.6].
- This lays extremely high n-yield (more than one order of magnitude above other plastics).
- Thicknesses of jacket not stated in Datasheets (sample arriving this week).
- Based on upper thresholds [which are not bad themselves], (a,n) killing us.
- Considering 4 jackets (2 x AWG24 + 2 x AWG28). Same length as fibers.

| Component | position or | | material | [kg] | n in 100 t yr | n bg / (100 t yr) |
|---|---|---|---|---|---|---|
| | #/PDM | g/m | | | | |
| Cathode HV | TPC side | 7.1E+2 | Cu | 4.2E+0 | 2.5E-2 | 8.2E-7 |
| LV, HV, control cable top | TPC top/bo | 7.2E-1 | Cu Luvata for cables | 1.5E+1 | 3.9E+1 | 1.3E-3 |
| LV, HV, control cable insu | TPC top/bo | 7.6E-1 | SAMI cable FEP | 1.5E+1 | 6.6E+2 | 2.2E-2 |
| LV, HV, control cable bot | TPC top/bo | 1.8E+0 | Cu Luvata for cables | 3.6E+1 | 9.5E+1 | 3.1E-3 |
| LV, HV, control cable insu | TPC top/bo | 7.6E-1 | SAMI cable FEP | 1.5E+1 | 6.6E+2 | 2.2E-2 |
| LV, HV, control cable bot | Inner veto | 1.8E+0 | Cu Luvata for cables | 4.8E+1 | 1.3E+2 | 2.9E-4 |
| LV, HV, control cable insu | Inner veto | 7.6E-1 | SAMI cable FEP | 2.1E+1 | 8.8E+2 | 2.0E-3 |

# Conclusions

**Dominance (urgent stuff?)** To be addressed as soon as we get samples. Chemical composition critical. Thicknesses, too.

**Everything assayed?** Nope.

**Needed more assays (complete chain or enhance sensitivity)?** more sensitivity needed + Po-210.

**MC status:** MC input from SiPMs position, reflector and veto. Needs to be improved.

# SiPMs

Resistors and capacitors: Huge Po-210 activity. Several candidates being assayed.

Harwin clips: Assay from december unusually high in mid U chain (1.6 Bq/kg).

Glass being evaluated. No results, yet, as far as I know.

# SiPMs

| Component | position or | | material | [kg] | n in 100 t yr | n bg / (100 t yr) |
|---|---|---|---|---|---|---|
| | #/PDM | \| mg/u | | [mg/PDM] | | |
| **SiPM tiles** | | | | | | **9.7E-2** |
| SiPMs | 24 | | Si SiPM | 2000 | 3.3E-1 | 6.4E-6 |
| SiPM "glue" | 1 | | | | 0.0E+0 | 0.0E+0 |
| Dielectric PCB | 1 | | pyralux | 3800 | 1.8E+2 | 3.5E-3 |
| Cu Luvata | 1 | | Cu Luvata | 1600 | 3.5E+1 | 6.8E-4 |
| Invar against contractior | 1 | | invar | 10125 | 2.4E+1 | 4.5E-4 |
| PCB adhesive | 1 | | Acrylic adhesive | 250 | 3.3E+1 | 6.3E-4 |
| Connector | 2 | | connector | 175 | 1.2E+1 | 2.3E-4 |
| Res. 50 MOhm 588-HVC | 48 | 2 | Res. 50 MOhm 588-HVC0603T50 | 96 | 3.2E+3 | 6.1E-2 |
| Res. 10.7 kOhm CPF0402 | 11 | 0.65 | resistor | 7.15 | 1.0E+2 | 2.0E-3 |
| Res. 10 Ohm CPF0402B1 | 12 | 0.65 | resistor | 7.8 | 1.1E+2 | 2.1E-3 |
| Res. 50 Ohm CPFA0402B | 12 | 0.65 | resistor | 7.8 | 1.1E+2 | 2.1E-3 |
| Res. 1 kOhm CPFA0402B | 3 | 0.65 | resistor | 1.95 | 2.8E+1 | 5.4E-4 |
| Res. 250 Ohm CPF0402B | 6 | 0.65 | resistor | 3.9 | 5.6E+1 | 1.1E-3 |
| Res. 750 Ohm CPFA0402 | 1 | 0.65 | resistor | 0.65 | 9.3E+0 | 1.8E-4 |
| Res. 0 Ohm CRG0402ZR | 5 | 0.65 | resistor | 3.25 | 4.6E+1 | 8.9E-4 |
| Res. 5.11 Ohm 716-8153 | 18 | 0.65 | resistor | 11.7 | 1.7E+2 | 3.2E-3 |
| PEN Capacitor 100 nF EC | 4 | 10 | PEN cap 100 nF ECW-U1104V33 | 40 | 3.8E+2 | 7.2E-3 |
| Solder | 240 | 0.5 | Solder sphere | 120 | 2.3E+1 | 4.3E-4 |
| Clips for housing | 4 | 45.5 | Harwin clip | 182 | 5.4E+2 | 1.0E-2 |
| Glass | 0.2 | | Borosilicate glass | 0 | 0.0E+0 | 0.0E+0 |

# Front End Boards

Resistors and capacitors: Huge Po-210 activity. Several candidates being assayed.

Finished PCB was dirtier than expected. In principle, because of unnecessary layers. A new one going through the same process as final ones needs to be assayed.

Solder: Indalloy 290 looks decent. HPGe to assay Th and mid U mandatory.

LMH6629 close to 0.01 n/ (100 t y). Not ideal, not a showstopper.

# Front End Boards

| Component | position or | | material | [kg] | n in 100 t yr | n bg / (100 t yr) |
|---|---|---|---|---|---|---|
| | #/PDM | mg/u | | [mg/PDM] | | |
| **Front end board** | | | | | | **4.1E-2** |
| Dielectric PCB | 1 | | pyralux | 1230 | 5.9E+1 | 1.1E-3 |
| Cu Luvata | 1 | | Cu Luvata | 1700 | 3.8E+1 | 7.2E-4 |
| Finished PCB | 1 | | PCB CCL | 0 | 0.0E+0 | 0.0E+0 |
| PCB adhesive | 1 | | Acrylic adhesive | 250 | 3.3E+1 | 6.3E-4 |
| connectors tile | 2 | | Connector | 120 | 8.2E+0 | 1.6E-4 |
| connector to fingers | 1 | | Connector | 80 | 5.4E+0 | 1.0E-4 |
| Op. amplifiers LMH6629 | 4 | 19.5 | Chip LMH6629 | 78 | 3.8E+2 | 7.3E-3 |
| summing amplifier THS4 | 1 | 22.7 | Chip THS4521 | 22.7 | 7.8E+1 | 1.5E-3 |
| diff. amplifier OPA838 | 1 | 15.2 | Chip OPA838 | 15.2 | 5.1E+1 | 9.8E-4 |
| Res. 10 Ohm CPF0402B1 | 4 | 0.65 | resistor | 2.6 | 3.7E+1 | 7.1E-4 |
| Res. 50 Ohm CPFA0402B | 3 | 0.65 | resistor | 1.95 | 2.8E+1 | 5.4E-4 |
| PEN Capacitor 100 nF EC | 2 | 10 | PEN cap 100 nF ECW-U1104V33 | 20 | 1.9E+2 | 3.6E-3 |
| Panasonic PPS caps (1 uF | 3 | 24 | PPS cap 1 uF ECP-U1C105MA5 | 72 | 2.3E+2 | 4.5E-3 |
| Panasonic PPS caps (100 | 20 | 7 | PPS cap 100 nF ECP-U1C104MA5 | 140 | 4.5E+2 | 8.7E-3 |
| Tantalum caps (47 uF) 6T | 3 | 10 | Ta capacitor 47 uF 6TPH47MHA | 30 | 3.9E+1 | 7.4E-4 |
| Solder | 1 | | Solder Indalloy 290 | 1000 | 2.6E+2 | 5.1E-3 |
| diode | 1 | 11.8 | Zenner diode MMSZ5232BT1G | 11.8 | 4.1E+1 | 7.9E-4 |
| AVR microcontroller | 1 | | chip | 0 | 0.0E+0 | 0.0E+0 |
| Acrylic housing | 1 | | Acrylic housing | 18000 | 1.7E+2 | 3.4E-3 |
| mushrooms | 2 | | Cu | 7000 | 3.4E-1 | 6.6E-6 |
| Circlip (seeger) | 4 | | SS DS50 | 500 | 1.1E+0 | 2.1E-5 |

# Conclusions (coming tender)

**Dominance (urgent stuff?)** Resistors and capacitors are absolutely urgent. Everything that should go in the tender has top priority.

**Everything assayed?** Nope.

**Needed more assays (complete chain or enhance sensitivity)?** Yes, a lot. Resistors and caps ongoing. Clips to be reassayed. PCBs to be reassayed. Solder HPGe pending.

**MC status:** MC input OK.

# PE rest 1

| Component | position or | | material | [kg] | n in 100 t yr | n bg / (100 t yr) |
|---|---|---|---|---|---|---|
| | #/PDM | mg/u | | [mg/PDM] | | |
| **Steering module** | (1/25 PDM | | | | | |
| | 0.04 | | | | | |
| Dielectric PCB | 1 | | pyralux | 90 | 4.3E+0 | 8.3E-5 |
| Cu Luvata | 1 | | Cu Luvata | 790 | 1.7E+1 | 3.4E-4 |
| Finished PCB | 1 | | PCB CCL | 0 | 0.0E+0 | 0.0E+0 |
| PCB adhesive | 1 | | Acrylic adhesive | 250 | 3.3E+1 | 6.3E-4 |
| Resistor (number?) | 25 | | resistor | 100 | 1.4E+3 | 2.7E-2 |
| Capacitor (number?) | 25 | | PPS capacitor | 100 | 1.1E+1 | 2.2E-4 |
| Solder | 1 | | Solder Indalloy 290 | 500 | 1.3E+2 | 2.5E-3 |
| Chip HV5523 | 2 | | chip | 500 | 1.4E+3 | 2.6E-2 |
| Chip HV3418 | 1 | | chip | 1000 | 2.7E+3 | 5.2E-2 |
| Connector to fingers | 1 | | connector | 500 | 3.4E+1 | 6.5E-4 |
| Connector to Opt. Mod | 1 | | connector | 500 | 3.4E+1 | 6.5E-4 |
| Connector to HV | 1 | | connector | 500 | 3.4E+1 | 6.5E-4 |
| Connector to LV? | 1 | | connector | 500 | 3.4E+1 | 6.5E-4 |
| LV, HV, control cable | 0.04 | | SAMI cable Cu | 2640 | 0.0E+0 | 0.0E+0 |
| LV, HV, control cable insu | 0.04 | | SAMI cable FEP | 300 | 1.1E+2 | 2.0E-3 |

# PE rest 2

| Component | position or | | material | mass [kg] | n in 100 t yr | n bg / (100 t yr) |
|---|---|---|---|---|---|---|
| | #/PDM | \| mg/u | | [mg/PDM] | | |
| **Mother board** | (1/25 PDM | | | | | |
| Cu plate | 0.04 | | Cu | 8.1E+4 | 3.9E+0 | 7.6E-5 |
| | | | | | | |
| **Finger board** | (2/25 PDM | | | | | |
| Dielectric PCB | 1 | | pyralux | 460 | 2.2E+1 | 4.2E-4 |
| Cu Luvata | 1 | | Cu Luvata | 384 | 8.5E+0 | 1.6E-4 |
| Finished PCB | 1 | | PCB CCL | 0 | 0.0E+0 | 0.0E+0 |
| PCB adhesive | 1 | | Acrylic adhesive | 250 | 3.3E+1 | 6.3E-4 |
| Connector to PDM | 12.5 | | Conn. Harwin long | 146 | 4.2E+0 | 8.0E-5 |
| Connector to Steering | 1 | | Conn. Harwin long | 200 | 5.7E+0 | 1.1E-4 |
| Solder | 1 | | Solder Indalloy 290 | 10 | 2.6E+0 | 5.1E-5 |
| | | | | | | |
| **Optical Module** | (1/25 PDM | | | | | |
| Dielectric PCB | 1 | | pyralux | 270 | 1.3E+1 | 2.5E-4 |
| Cu Luvata | 1 | | Cu Luvata | 380 | 8.4E+0 | 1.6E-4 |
| Finished PCB | 1 | | PCB CCL | 0 | 0.0E+0 | 0.0E+0 |
| PCB adhesive | 1 | | Acrylic adhesive | 250 | 3.3E+1 | 6.3E-4 |
| Connector | 1 | | connector | 100 | 6.8E+0 | 1.3E-4 |
| Amplifier | 1 | | chip | 33 | 9.0E+1 | 1.7E-3 |
| Resistor | | | resistor | 33 | 4.7E+2 | 9.1E-3 |
| Capacitor | | | PEN cap 100 nF ECW-U1104V33 | 33 | 3.1E+2 | 6.0E-3 |
| LED | 25 | | LED (op. driver) | 264 | 2.4E+3 | 4.7E-2 |

# Conclusions

**Dominance (urgent stuff?)** LED critical for experiment, although called “Pb-free”, has a lot of Po-210. Chips HV5523, HV3418 not assayed. Resistors and capacitors.

**Everything assayed?** Nope.

**Needed more assays (complete chain or enhance sensitivity)?** Assay LED lens separately? Chips.

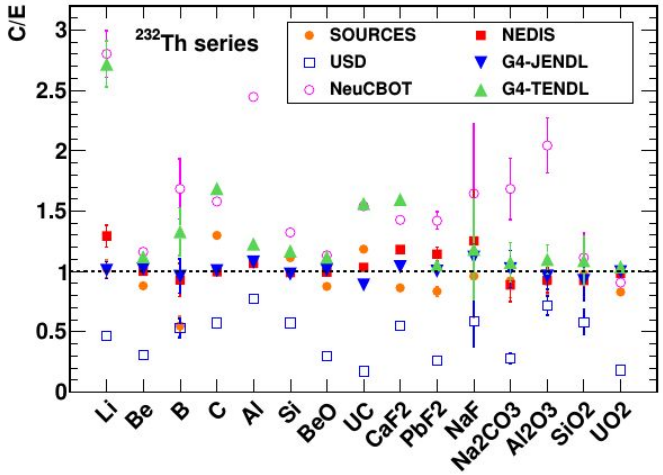
**MC status:** MC input OK.

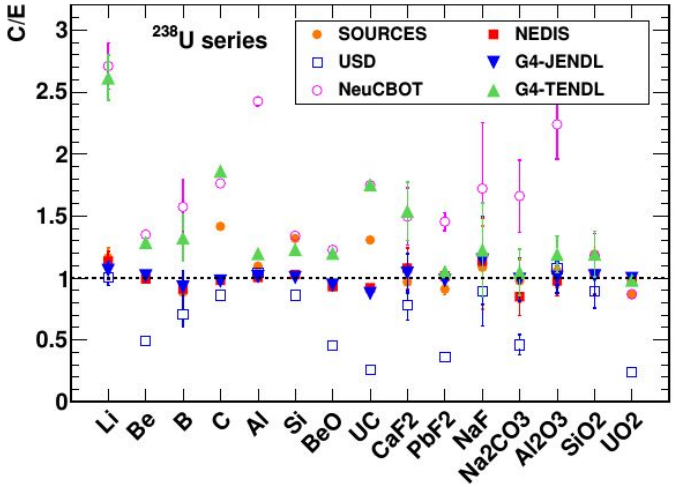
# (a,n) calculations using Geant4

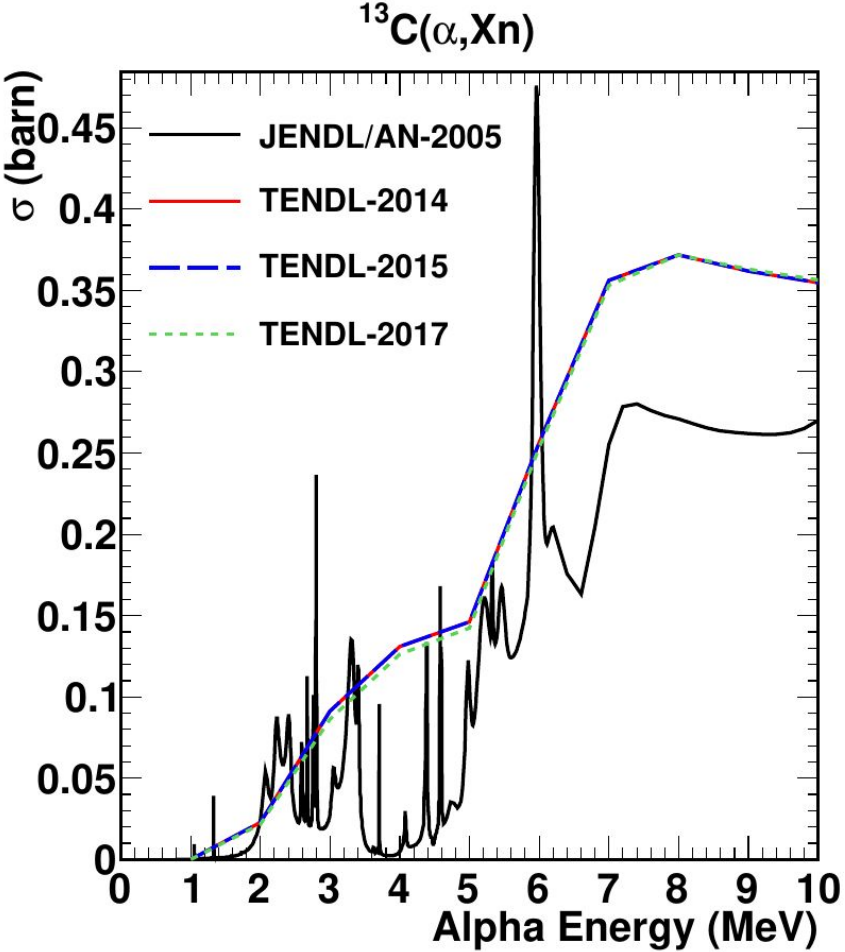
Code validated versus SOURCES, NEDIS, USD, NeuCBOT.

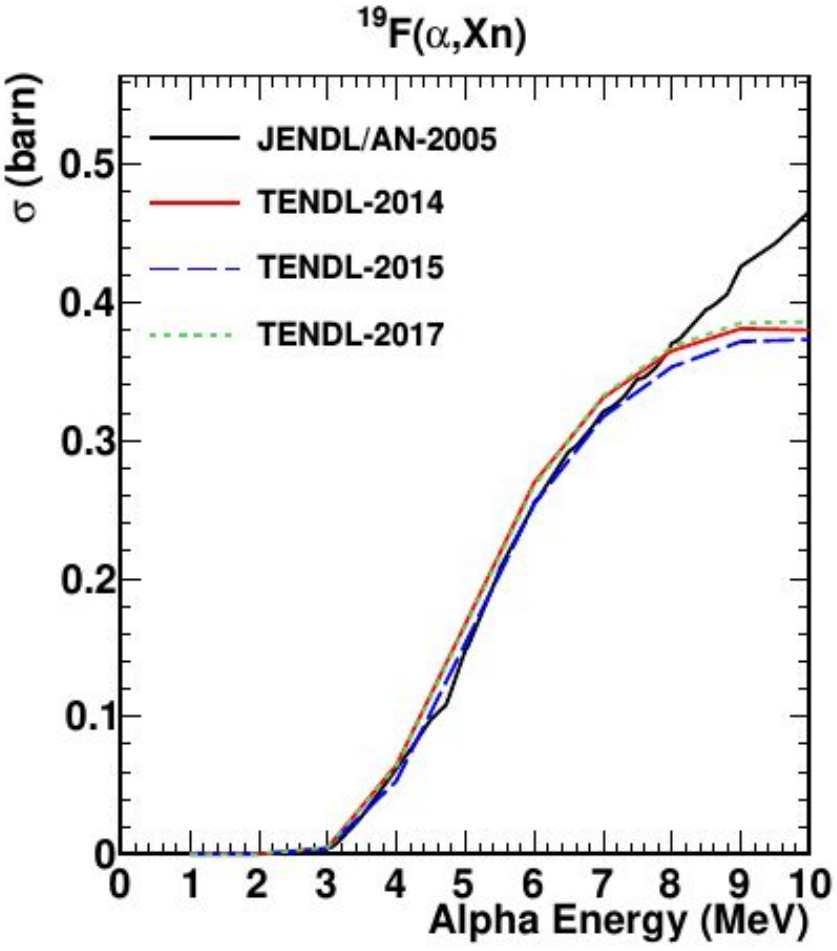
Code run using libraries from JENDL (experimental) and TENDL.

Preliminary: Agrees better to experimental data, and 40-60% below NeuCBOT




$^{13}$C(α,Xn)
σ (barn)
JENDL/AN-2005
TENDL-2014
TENDL-2015
TENDL-2017
Alpha Energy (MeV)


$^{19}$F(α,Xn)
σ (barn)
JENDL/AN-2005
TENDL-2014
TENDL-2015
TENDL-2017
Alpha Energy (MeV)

# Radioactive budget for proto

Recently updated after interaction with C. Savarese.

The fact that PDMs are still evolving but some of them are already finished makes it difficult to predict overall activity.

- We'll have many different motherboards.

Simulations very sensitive to the design changes still under discussion.

Simulations with 5 cm TPC walls ongoing.