



**Pacific  
Northwest**  
NATIONAL LABORATORY

# Community Online Tools

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U.S. DEPARTMENT OF  
**ENERGY** **BATTELLE**

PNNL is operated by Battelle for the U.S. Department of  
Energy



# Common tasks for low background detectors

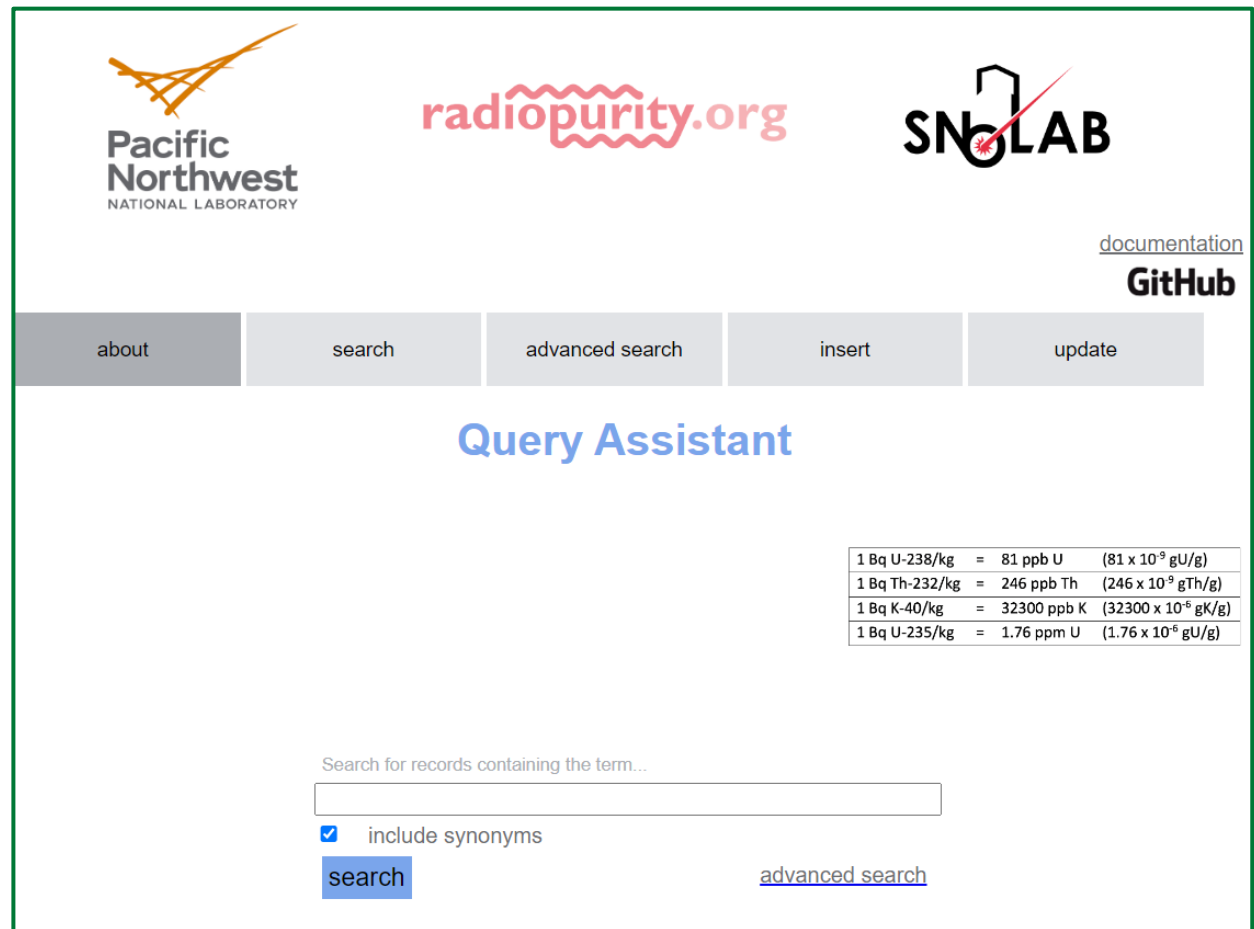
- Track and share radioactivity assay measurements

radiopurity.org

- Predict the background budget for each component and material



- Main site radiopurity.org hosted by SNOLAB
- Private collections can be visible to collaboration members only and later made public
  - SNOLAB HPGE
  - SuperCDMS
  - nEXO
- Or run a server locally
  - DUNE at PNNL



The screenshot shows the radiopurity.org website interface. At the top, there are logos for Pacific Northwest National Laboratory, radiopurity.org, and SNOLAB. Below the logos, there are links for "documentation" and "GitHub". A navigation bar contains buttons for "about", "search", "advanced search", "insert", and "update". The main content area features the heading "Query Assistant" and a table of conversion factors:

1 Bq U-238/kg	= 81 ppb U	(81 x 10 <sup>-9</sup> gU/g)
1 Bq Th-232/kg	= 246 ppb Th	(246 x 10 <sup>-9</sup> gTh/g)
1 Bq K-40/kg	= 32300 ppb K	(32300 x 10 <sup>-6</sup> gK/g)
1 Bq U-235/kg	= 1.76 ppm U	(1.76 x 10 <sup>-6</sup> gU/g)

Below the table is a search input field with the placeholder text "Search for records containing the term...". There is a checked checkbox for "include synonyms" and a "search" button. A link for "advanced search" is also present.



## DATA FORMAT

**Material Assay Data Format (MADF)**  
Standardized, but flexible, json format

## INTERFACE

### Database Assistant

Open source format for storing, displaying and manipulating MADFs

### Public instance maintained by SNOLAB

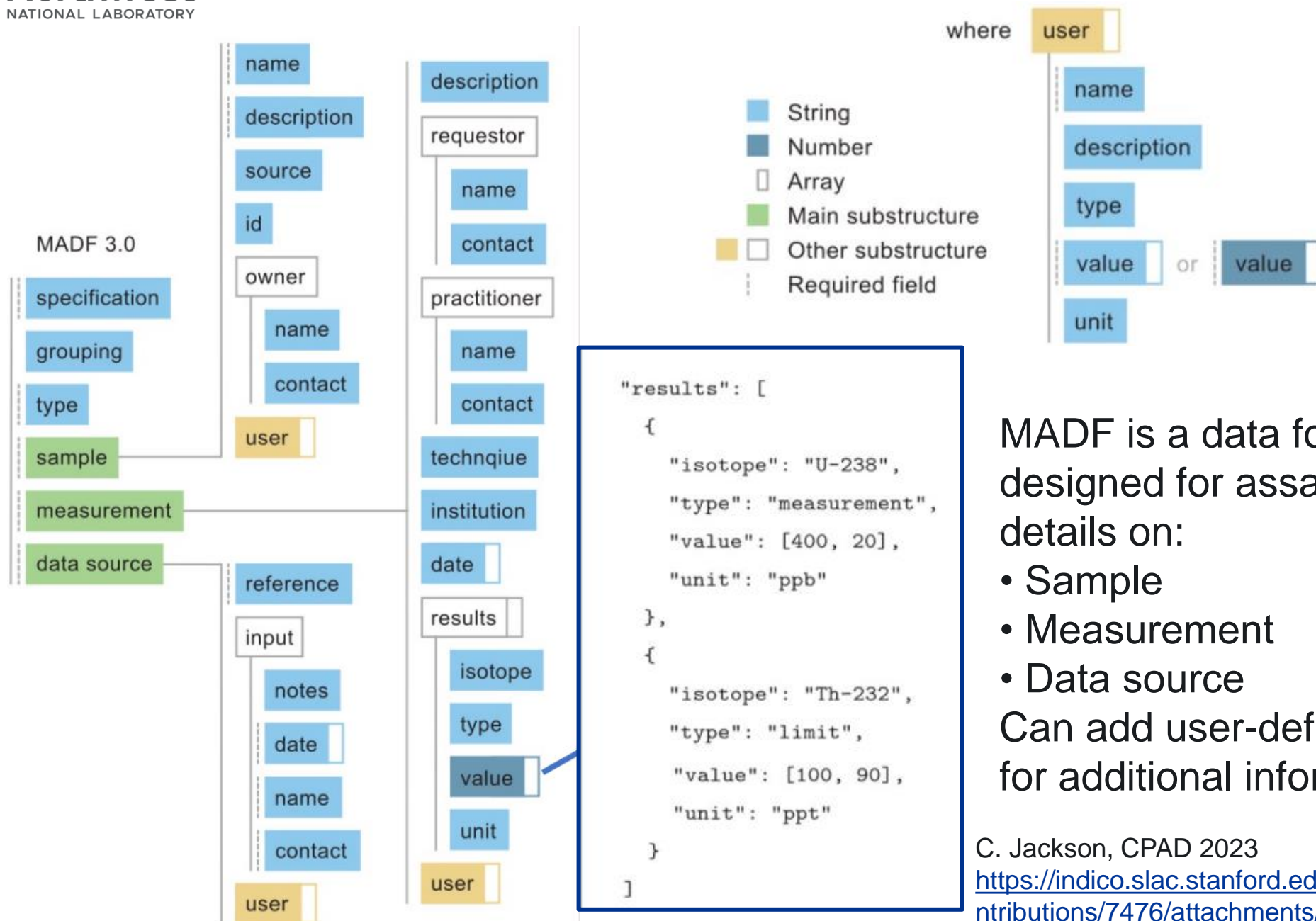
<https://www.radiopurity.org/>

Can share results easily with community when ready

S. Sekula, TAUP 2023

<https://indico.cern.ch/event/1199289/contributions/5445810/attachments/2703590/4692931/2023-08-TAUP-Radiopurity-org-Sekula.pdf>

# Material Assay Data Format (MADF)



MADF is a data format designed for assays. Tracks details on:

- Sample
- Measurement
- Data source

Can add user-defined fields for additional information

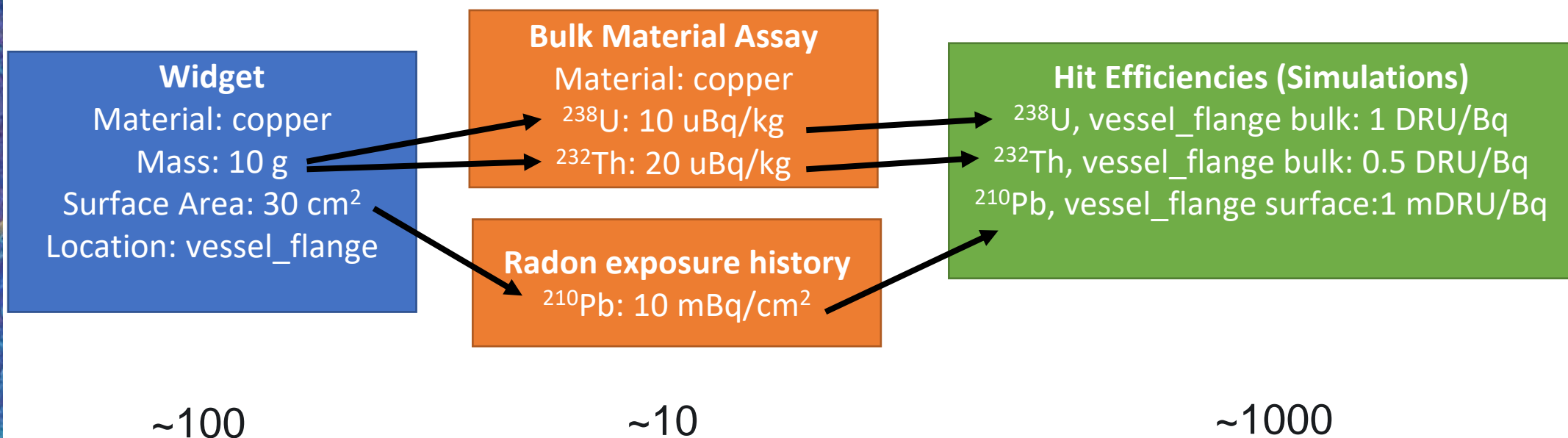
C. Jackson, CPAD 2023

<https://indico.slac.stanford.edu/event/8288/contributions/7476/attachments/3614/9916/radiopurityDatabasePoster.pdf>

# Radiopurity.org future plans

- SNOLAB hosts and maintains main site
- Development supported by US DOE Detector R&D program
- Planned capability for Azure cloud deployment for full reliability/uptime
- Make it easier to share internal data to main site when ready to publish
- Community feedback is welcome! Contact [radiopurity@snolab.ca](mailto:radiopurity@snolab.ca) with suggestions or data to share

# Building a background model





# Model definitions

- All components and radiopurity specs contained in a single document
- Full version history preserved
- Multiple versions can test design alternatives

## Editing Model: HPGE Detector

Sample low background HPGE counter

Components Specifications

Search  ✕

### Components

Create new:

Name	Description	Status
<b>Assembly Tree</b>		
HPGE System ↕	Low background shielded HPGE detector	
detector housing ↕		
can		
top lid		
bottom lid		
M4x1.5 screw		
sample holder	HDPE blocks for placing large samples	
shield ↕	copper and lead shielding	
copper box ↕		
cuBox_top		
cuBox_bot		

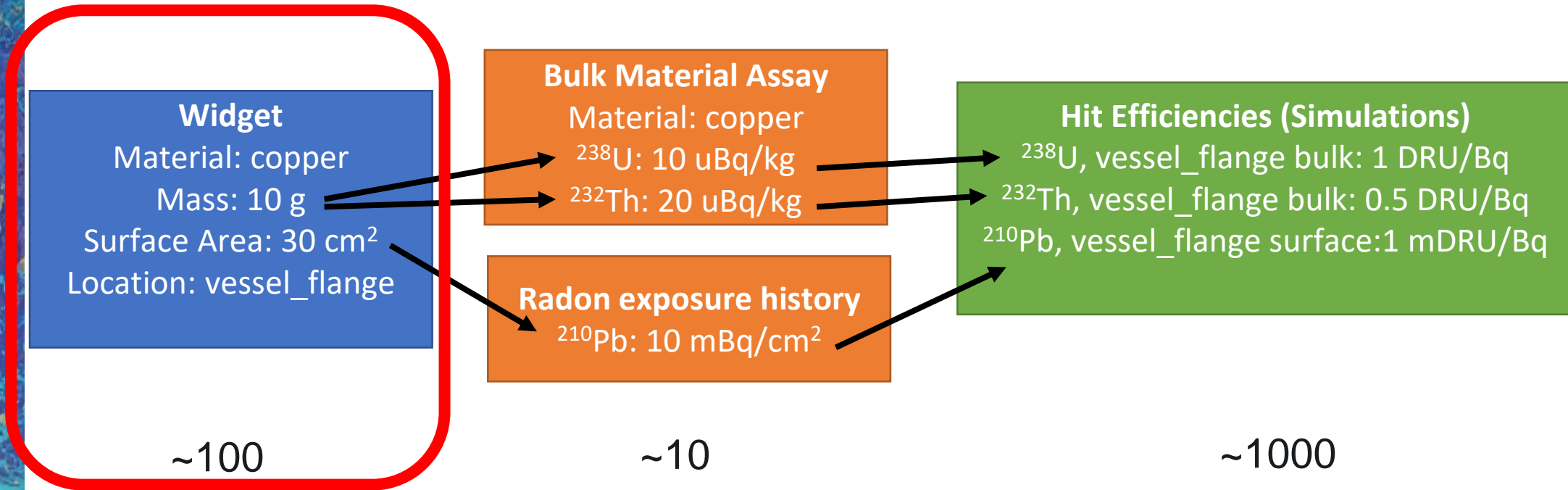
## List of Models

Create New

Name	Version
HPGE Detector	6.0 ▲
<i>HPGE Detector</i>	5.0
<i>HPGE Detector</i>	4.0
<i>HPGE Detector</i>	3.1
<i>HPGE Detector</i>	3.0
<i>HPGE Detector</i>	2.0
<i>HPGE Detector</i>	1.0
HPGE Detector test	1.0
HPGE Detector testing bad spec	1.0



# Building a background model



# Define components

Components placed into (nested) hierarchy of Assemblies. Multiple “copies” can be in different places

Components associated with multiple “Emission specs” (bulk contam, cosmogenic activation, radon or dust exposure)

Components Specifications

Search ✕

**Components** Create new: Component Assembly

- detector housing ▾
- can
- top lid
- bottom lid
- M4x1.5 screw
- sample holder HDPE blocks for placing large samples
- shield ▾ copper and lead shielding
- copper box ▾
- cuBox\_top
- cuBox\_bot
- cuBox\_side
- cuBox\_frt
- cuBox\_bck
- M4x1.5 screw

## Edit Component

Save Other actions ▾

**Emission specs**

Name	Category	Dist.	Query
copper contam	RadioactiveContam	bulk	<span>🔧</span> <span>✕</span>

+ Add

**Material**

brass

**Mass**

0.5 g

**Volume**

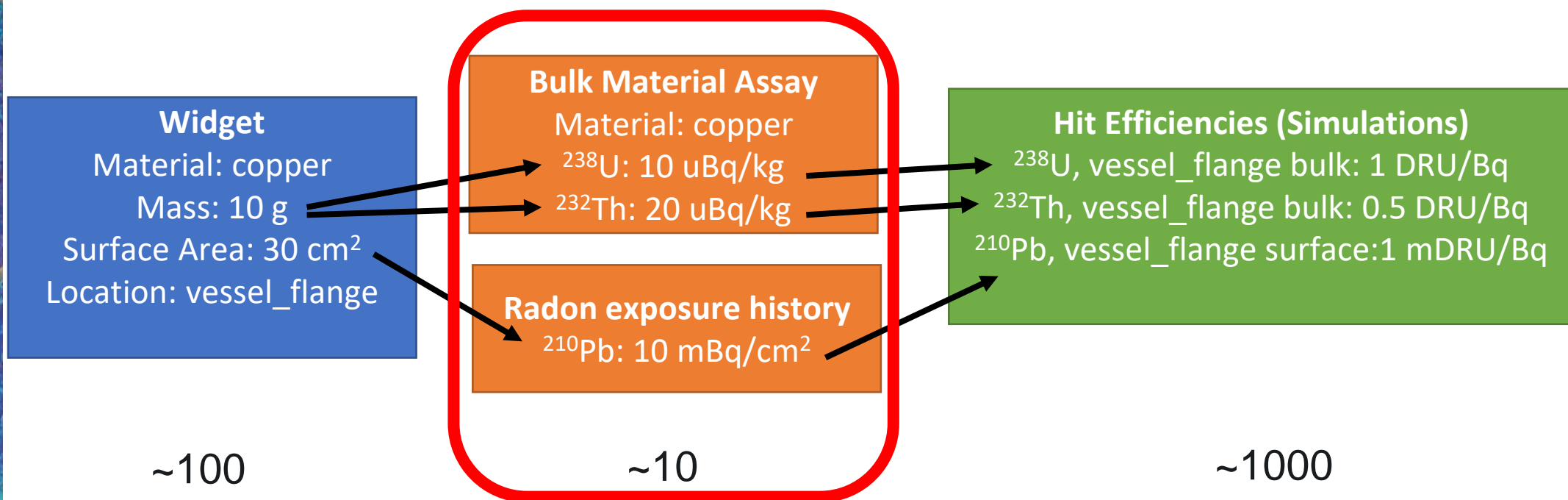
0 cm<sup>3</sup>

**Inner Surface**

0 cm<sup>2</sup>

**Outer Surface**

# Building a background model



# Define Emission Specs

Multiple radioactive source specifications with uncertainties or limits. Can override database queries and normalization to handle edge cases.

Components Specifications

Search ✕

**Specifications** Create new: Select a spec type

Name	Category	Dist.	Rate	Status
copper contam	RadioactiveContam	bulk	$(1.1 \pm 0.2) \times 10^2$ $\mu$ Bq/kg	
aluminum contam	RadioactiveContam	bulk	$(1.3 \pm 0.1) \times 10^2$ mBq/kg	
copper activation	CosmogenicActivation	bulk	61 1/d/kg	
cavern flux	RadioactiveContam	flux	2.1 1/cm <sup>2</sup> /s	
HDPE contam	RadioactiveContam	bulk	$(6.2 \pm 0.5) \times 10^3$ pptU	
lead contam	RadioactiveContam	bulk	$(3.3 \pm 0.0) \times 10^7$ pptU	

+ Add

## Edit Specification

Save Other actions ▾

Custom rate normalization function. Will be using 'eval', with variables 'component' and 'units' defined. Can also be 'piece' or 'per piece' indicating that the rate is already normalized

Query Modifier 🔧

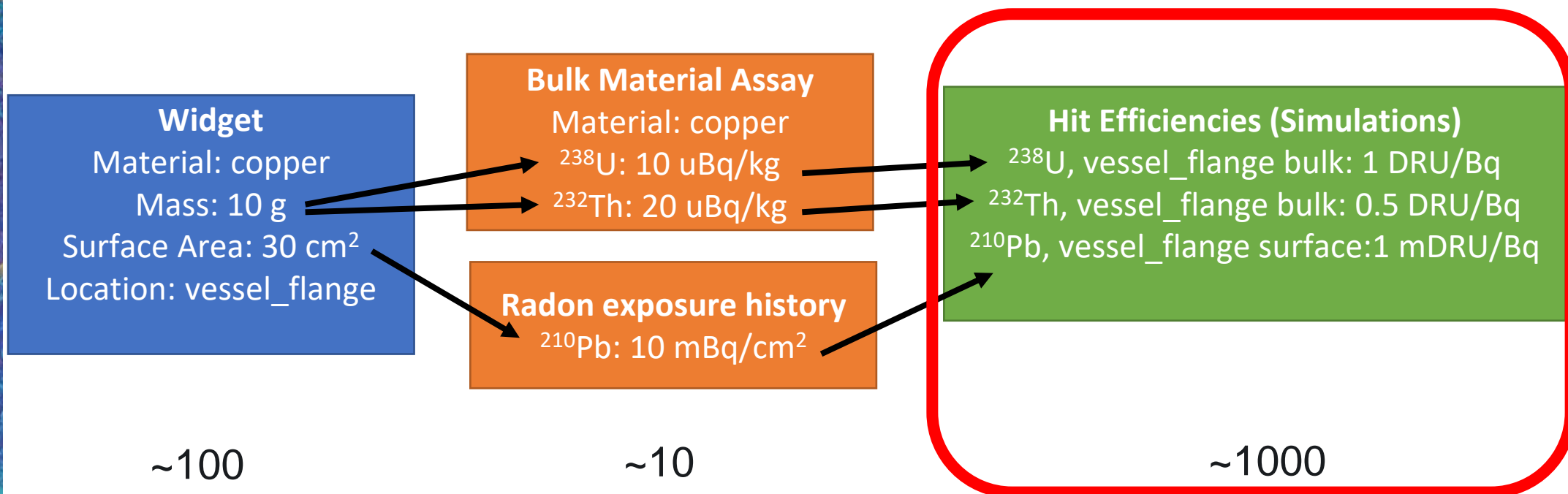
Overrides for generating simulation database queries

**Isotopes**

Isotope	Decay rate	Uncertainty	Limit?	
<span style="border: 1px solid #ccc; padding: 2px;">U238</span>	<span style="border: 1px solid #ccc; padding: 2px;">108 mBq/kg</span>	<span style="border: 1px solid #ccc; padding: 2px;">0.0462962962962</span>	<input type="checkbox"/>	✕
<span style="border: 1px solid #ccc; padding: 2px;">Th232</span>	<span style="border: 1px solid #ccc; padding: 2px;">5.6 mBq/kg</span>	<span style="border: 1px solid #ccc; padding: 2px;">0.25</span>	<input type="checkbox"/>	✕
<span style="border: 1px solid #ccc; padding: 2px;">K40</span>	<span style="border: 1px solid #ccc; padding: 2px;">10 mBq/kg</span>	<span style="border: 1px solid #ccc; padding: 2px;">0.5</span>	<input type="checkbox"/>	✕
<span style="border: 1px solid #ccc; padding: 2px;">Cs137</span>	<span style="border: 1px solid #ccc; padding: 2px;">1.28 mBq/kg</span>	<span style="border: 1px solid #ccc; padding: 2px;">0</span>	<input checked="" type="checkbox"/>	✕
<span style="border: 1px solid #ccc; padding: 2px;">Co60</span>	<span style="border: 1px solid #ccc; padding: 2px;">0.71 mBq/kg</span>	<span style="border: 1px solid #ccc; padding: 2px;">0</span>	<input checked="" type="checkbox"/>	✕



# Building a background model



# Upload JSON Hit Efficiencies

## Upload Sim Data to [hpge](#)

Insert new entries into the simulations database

Select file(s) to upload or drag and drop

Files should be JSON or zipped archives.

### Data format options:

- Follow predefined format
  - Tell bgexplorer how to interpret your data by subclassing SimulationDatabase
- OR

# Predefined data format

## Required attributes:

`source (str)`: What is the radiation source? Match name from assay, etc.

`location (str)`: Where the source is located relative to the detector  
usually the name of a MC volume

`distribution (str)`: whether the source is distributed in the bulk,  
on a surface, or some other way

`norm (NormMultiplier)`: To convert HitEfficiency to rates in detector,  
multiply by emission rate in some units,  
usually 'rate' (decays/s), but can be  
'flux' (primaries/s/cm\*\*2)  
'flux\_per\_sr' (primaries/s/cm\*\*2/sr) or  
'none' (HitEff is absolutely normalized)

`values (dict)`: Single-value hit efficiencies (as asymmetric uncertainties  
with units), such as integral counts over some ROI

`spectra (dict)`: histograms of hit efficiencies

## Suggested metadata:

`nprimaries`: number of primary particles simulated  
`primary_spectrum`: filename or representation of the spectrum of  
particles thrown e.g. simulating (alpha,n) neutrons  
`primary_particle`: name of primary particle  
`primary_yield`: when simulating e.g. neutrons or equilibrium gammas, the  
average neutrons or gammas emitted per parent isotope decay  
`biasweight`: any biasing applied to the simulation  
`livetime`: In rare cases the simulation or spectrum is absolutely  
normalized, e.g. coherent neutrino backgrounds or dark current  
In this case livetime can be recorded rather than calculated  
`version`: software version information  
`files`: filenames used for calculation  
`uuids`: UUIDs of files used  
`date`: date entry was created

If `nprimaries` is provided, the simulation livetime will be displayed where  
appropriate as  $(nprimaries * biasweight / (emissionrate * yield))$

Queries against the database are made against (source, location, distr.).  
Multiple responses are grouped by (primary\_particle, primary\_spectrum).

# Match components and emission specs to specific Hit Efficiencies

Bind Simdata for model HPGE Detector v6.0

Save bindings

Cancel

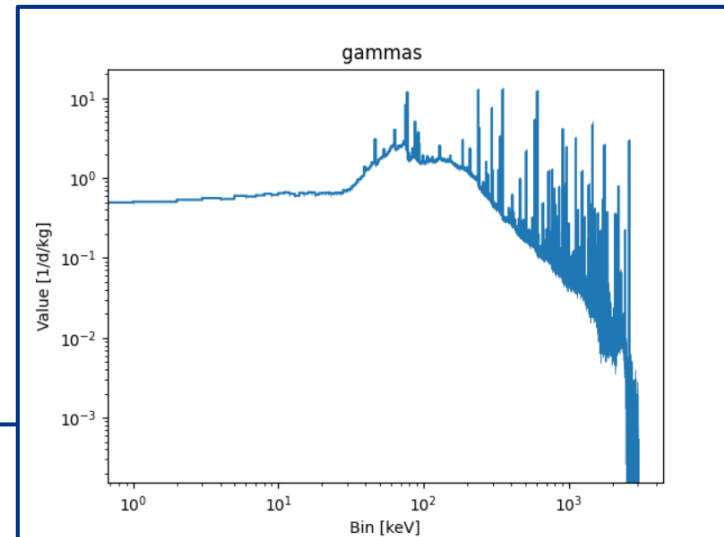
Search:

Path	Spec	Rate per day	DB query	DB hits	Livetime (days)
detector housing / can	U238 bulk	(4.67+/-0.22)e+03	{'volume': 'can1', 'primary': '92-238', 'spectrum': None}	1, 2	(2.16+/-0.10)e+03
detector housing / can	Th232 bulk	(2.42+/-0.60)e+02	{'volume': 'can1', 'primary': '90-232', 'spectrum': None}	1, 2	(4.17+/-1.04)e+04
detector housing / can	K40 bulk	(4.32+/-2.16)e+02	{'volume': 'can1', 'primary': '19-40', 'spectrum': None}	1, 2	(2.34+/-1.17)e+04
detector housing / can	Cs137 bulk	< 5.53e+01	{'volume': 'can1', 'primary': '55-137', 'spectrum': None}		0.00e+00
detector housing / can	Co60 bulk	< 3.07e+01	{'volume': 'can1', 'primary': '27-60', 'spectrum': None}	1, 2	3.29e+05
detector housing / top lid	U238 bulk	(3.10+/-0.14)e+02	{'volume': 'lid1', 'primary': '92-238', 'spectrum': None}	1, 2	(3.26+/-0.15)e+04
detector housing / top lid	Th232 bulk	(1.61+/-0.40)e+01	{'volume': 'lid1', 'primary': '90-232', 'spectrum': None}	1, 2	(6.28+/-1.57)e+05
detector housing / top lid	K40 bulk	(2.87+/-1.44)e+01	{'volume': 'lid1', 'primary': '19-40', 'spectrum': None}	1, 2	(3.52+/-1.76)e+05
detector housing / top lid	Cs137 bulk	< 3.68e+00	{'volume': 'lid1', 'primary': '55-137', 'spectrum': None}		0.00e+00
detector housing / top lid	Co60 bulk	< 2.04e+00	{'volume': 'lid1', 'primary': '27-60', 'spectrum': None}	1, 2	4.95e+06
detector housing / bottom lid	U238 bulk	(9.70+/-0.45)e+02	{'volume': 'lid2', 'primary': '92-238', 'spectrum': None}	1, 2	(1.04+/-0.05)e+04
detector housing / bottom lid	Th232 bulk	(5.03+/-1.26)e+01	{'volume': 'lid2', 'primary': '90-232', 'spectrum': None}	1, 2	(2.01+/-0.50)e+05
detector housing / bottom lid	K40 bulk	(8.98+/-4.49)e+01	{'volume': 'lid2', 'primary': '19-40', 'spectrum': None}	1, 2	(1.13+/-0.56)e+05
detector housing / bottom lid	Cs137 bulk	< 1.15e+01	{'volume': 'lid2', 'primary': '55-137', 'spectrum': None}		0.00e+00



# Explore results

Each cell is a link to generate a spectrum



## Evaluated Rate Tables

The number in parentheses is the nominal 1-sigma error. Hover over the numbers to see the result with longer precision. Click on the numbers to view the associated spectrum.

Component	Gammas, 0.1-5 keV [dru]	Gammas, 3-100 keV [dru]	Gammas, 10-2000 keV [dru]
Total ▾	2.91(9)	60(10)	14(1)
detector housing ▾	2.28(9)	8.7(3)	1.55(5)
can	1.84(8)	7.1(3)	1.25(5)
top lid	0.32(1)	1.23(5)	0.23(1)
bottom lid	0.111(5)	0.37(2)	0.067(3)
M4x1.5 screw	0.000(1)	0.000(4)	0.000(8)
sample holder	0.53(2)	1.77(8)	0.32(1)
shield ▾	0.108(4)	50(10)	12(1)
copper box ▶	0.098(4)	0.136(6)	0.061(2)
lead shield	<0.010	50(10)	12(1)

# Explore results with dynamic filters

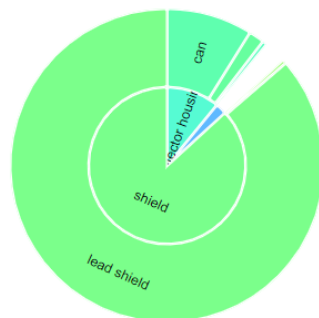
## Filter Info

60 / 60 (100.0%) records pass all filters.  
14.1 / 14.1 dru (100.0%) rate pass all filters.

Active Filters [reset all](#)

Component:  
Material:  
Source:

## Component



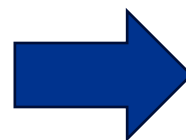
## Filter Info

56 / 60 (93.3%) records pass all filters.  
1.93 / 14.1 dru (13.6%) rate pass all filters.

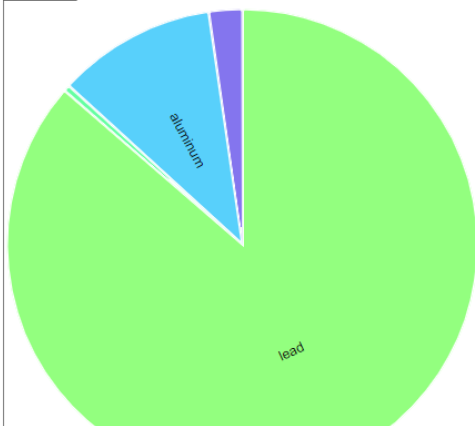
Active Filters [reset all](#)

Component:  
Material:  
◦ ! lead ✖  
Source:

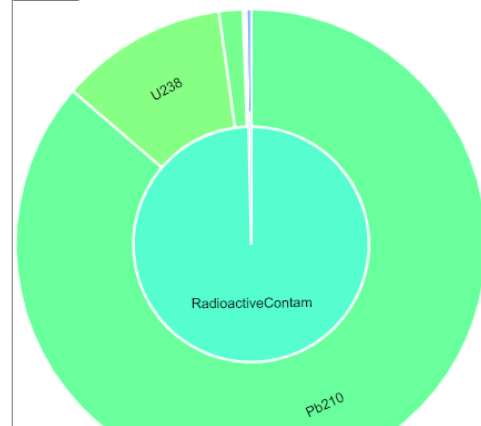
## Component



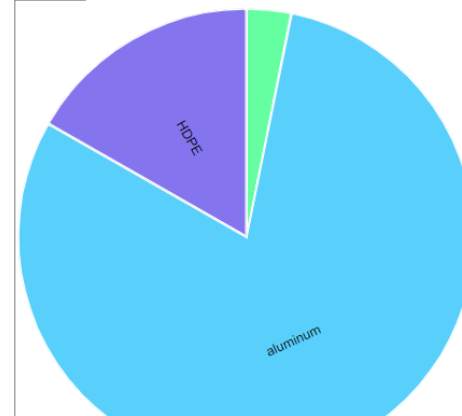
## Material



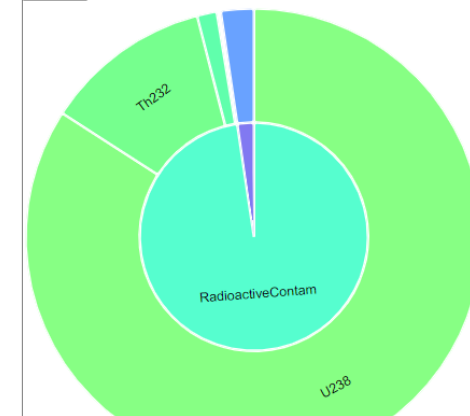
## Source



## Material



## Source





# Export calculation results to CSV

ID	G_Component	G_Material	G_Source	V_Gammas, 0.1-5 keV [dru]	V_Gammas, 3-100 keV [dru]	V_Gammas, 10-2000 keV [dru]
eHGvmSFS9L8krEL9CrBK5Y6	detector housing__can	aluminum	aluminum	RadioactiveContam__U238	1.72+/-0.08	6.64+/-0.31 1.17+/-0.05
YJUKYyrrnXm456RGo3SDTPW	detector housing__can	aluminum	aluminum	RadioactiveContam__Th232	0.110+/-0.028	0.419+/-0.105 0.0701+/-0.0175
HBHUDM6agoP4pYdJdB7wiP	detector housing__can	aluminum	aluminum	RadioactiveContam__K40	0.00656+/-0.00329	0.0270+/-0.0135 0.00775+/-0.00388
jd4aymQ8q7EokHLF9B54es	detector housing__can	aluminum	aluminum	RadioactiveContam__Cs137	<0	<0
jJDFGcsK6v5r9n2kFsvyfw	detector housing__can	aluminum	aluminum	RadioactiveContam__Co60	<0.00415+/-0.00006	<0.00511+/-0.00001 <0.00426+/-0.00000
ZXmjFzdp3MwmRt5nWKNXVP	detector housing__top lid	aluminum	aluminum	RadioactiveContam__U238	0.303+/-0.014	1.16+/-0.05 0.212+/-0.010
brsBqxDiHk5EuLV3McPESq	detector housing__top lid	aluminum	aluminum	RadioactiveContam__Th232	0.0188+/-0.0047	0.0678+/-0.0170 0.0119+/-0.0030
aFdsGbAh3erFqfKf5hNTxm	detector housing__top lid	aluminum	aluminum	RadioactiveContam__K40	0.00124+/-0.00062	0.00531+/-0.00266 0.00173+/-0.00086
WKA6r7tMngh9wT5P2PoPus	detector housing__top lid	aluminum	aluminum	RadioactiveContam__Cs137	<0	<0
3KjoFimQbgzjXdiRmcg4sQ	detector housing__top lid	aluminum	aluminum	RadioactiveContam__Co60	<0.000608+/-0.00006	<0.000683+/-0.00001 <0.000662+/-0.00000
PPNzJf4tzPvrZgzpjbvB89	detector housing__bottom lid	aluminum	aluminum	RadioactiveContam__U238	0.103+/-0.005	0.348+/-0.016 0.0621+/-0.0029
LffvVeygaRaUbD6gzTuUnj	detector housing__bottom lid	aluminum	aluminum	RadioactiveContam__Th232	0.00685+/-0.00171	0.0233+/-0.0058 0.00393+/-0.00098
WARmx9z5L7uk4qPfeBwHRi	detector housing__bottom lid	aluminum	aluminum	RadioactiveContam__K40	0.000401+/-0.000203	0.00138+/-0.00069 0.000378+/-0.000189
fbU6MUDqLsidP6bGEEXJwN	detector housing__bottom lid	aluminum	aluminum	RadioactiveContam__Cs137	<0	<0
FHoPPUF6HkAt4CrcutpckQ	detector housing__bottom lid	aluminum	aluminum	RadioactiveContam__Co60	<0.000377+/-0.000008	<0.000488+/-0.000002 <0.000260+/-0.000000
JA8xBwrpsW4BigTbajWjTY	detector housing__M4x1.5 screw	brass	brass	RadioactiveContam__U238	(3.54+/-1.01)e-05	0.000136+/-0.000039 (2.48+/-0.71)e-05
7XoKvGTQocMR6bNKGD4u3s	detector housing__M4x1.5 screw	brass	brass	RadioactiveContam__Th232	(1.27+/-0.42)e-05	(4.59+/-1.53)e-05 (8.07+/-2.69)e-06
Ufv2Lu3b2ntQ3CS8KsaYq2	detector housing__M4x1.5 screw	brass	brass	RadioactiveContam__K40	(5.16+/-1.35)e-07	(2.21+/-0.58)e-06 (7.17+/-1.87)e-07
70979003-0bce-405e-b43b-65cd014bd2c9	sample holder	HDPE	HDPE	RadioactiveContam__U238	0.277+/-0.018	0.905+/-0.057 0.167+/-0.010
cc7b7551-8cd2-4df1-a63f-032633b4d721	sample holder	HDPE	HDPE	RadioactiveContam__Th232	0.236+/-0.016	0.818+/-0.055 0.139+/-0.009
e136ffab-8b63-4478-b8cf-3d57829c9eb4	sample holder	HDPE	HDPE	RadioactiveContam__K40	0.0162+/-0.0029	0.0477+/-0.0068 0.0171+/-0.0024
cr569dJXHemtCoCShkv6wA	shield__copper	box__cuBox_top	copper	RadioactiveContam__U238	0.00275+/-0.00079	0.00344+/-0.00098 0.00133+/-0.00038
nA8hQcFsZWMeVJbEttYv8U	shield__copper	box__cuBox_top	copper	RadioactiveContam__Th232	0.000978+/-0.000328	0.00131+/-0.00044 0.000485+/-0.000162
BzdWYwZXc5LYFQ2Nhemoy	shield__copper	box__cuBox_top	copper	RadioactiveContam__K40	(5.48+/-1.69)e-05	(6.99+/-1.84)e-05 (3.25+/-0.85)e-05
fCyodheBfjDwNowWLSR7CB	shield__copper	box__cuBox_top	copper	CosmogenicActivation__Mn54	0	0
MgGseG6VS8VrWxw2Dd22Xk	shield__copper	box__cuBox_top	copper	CosmogenicActivation__Co57	0	0
FoGup4JGsdnJyyfjC9K9a2	shield__copper	box__cuBox_top	copper	CosmogenicActivation__Co60	0.00935+/-0.00037	0.0114+/-0.0001 0.00527+/-0.00001
GdWkEmFdZBrAQL4viCxCQjm	shield__copper	box__cuBox_bot	copper	RadioactiveContam__U238	0	0
Fy8wEzTLiE9282e8QYupWB	shield__copper	box__cuBox_bot	copper	RadioactiveContam__Th232	0	0
nfwHNf4YodFVJysv3gZy9F	shield__copper	box__cuBox_bot	copper	RadioactiveContam__K40	0	0
gMnn5Uyup4eaPWF7QJstqD	shield__copper	box__cuBox_bot	copper	CosmogenicActivation__Mn54	0	0
TFTi49gWHo82NjzSZTrkS5	shield__copper	box__cuBox_bot	copper	CosmogenicActivation__Co57	0	0
bXZbBoAJKDKavGeiC5eMeb	shield__copper	box__cuBox_bot	copper	CosmogenicActivation__Co60	0	0
iy2zkqenSMVgpF8GGvTuYe	shield__copper	box__cuBox_side	copper	RadioactiveContam__U238	0.00992+/-0.00284	0.0148+/-0.0042 0.00549+/-0.00157
2ZDuDbMNYrt3S4HF9rgRjXa	shield__copper	box__cuBox_side	copper	RadioactiveContam__Th232	0.00354+/-0.00118	0.00568+/-0.00189 0.00202+/-0.00067
LBQnc8UZ7mYsFTGaUhnCxc	shield__copper	box__cuBox_side	copper	RadioactiveContam__K40	0.000217+/-0.000061	0.000288+/-0.000075 0.000131+/-0.000034
7h9keAyjqokUgV3XdCTdyC	shield__copper	box__cuBox_side	copper	CosmogenicActivation__Mn54	0	0
cafPuyYjaSS9DAieg9j2is	shield__copper	box__cuBox_side	copper	CosmogenicActivation__Co57	0	0
4PmzuBTazZDzVhyRCXCRKf	shield__copper	box__cuBox_side	copper	CosmogenicActivation__Co60	0.0318+/-0.0008	0.0446+/-0.0002 0.0212+/-0.0000
ReWT5jzr8i6u6acvS32oFz	shield__copper	box__cuBox_frt	copper	RadioactiveContam__U238	0.00680+/-0.00195	0.00954+/-0.00273 0.00381+/-0.00109
FTsBamRusoTq7DdLKZgG6x	shield__copper	box__cuBox_frt	copper	RadioactiveContam__Th232	0.00253+/-0.00084	0.00362+/-0.00121 0.00138+/-0.00046
87KnbA4GUpbb4i2nHC86SS	shield__copper	box__cuBox_frt	copper	RadioactiveContam__K40	0.000129+/-0.000036	0.000177+/-0.000046 (8.87+/-2.31)e-05
raXacAv2hhFXKmxYmWRhnt	shield__copper	box__cuBox_frt	copper	CosmogenicActivation__Mn54	0	0

# Background Explorer Planned developments: version 3

- Finer-grained permissions (view, edit, delete)
- Configure all settings within web interface
- Improved handling of combinations of upper limits and uncertainties
- Attachments and part tracking
- Better version control
- Full test coverage



# Common technologies

- Python Flask server



- MongoDB database, easy conversion to/from JSON



- Docker containerization



Want to run your own server?

```
> git clone <repo>  
> docker compose up
```

## More info

[radiopurity.org](http://radiopurity.org)



- [radiopurity.org](http://radiopurity.org)
- [github.com/pnnl/Radiopurity-database-assistant](https://github.com/pnnl/Radiopurity-database-assistant)
- [radiopurity@snolab.org](mailto:radiopurity@snolab.org)
- Chris Jackson  
[christopher.jackson@pnnl.gov](mailto:christopher.jackson@pnnl.gov)
- [bgexplorer.pnnl.gov/demo](http://bgexplorer.pnnl.gov/demo)  
(user: demo , pass: bgexplorer)
- [github.com/bloer/bgexplorer](https://github.com/bloer/bgexplorer)
- [github.com/bloer/bgexplorer-docker](https://github.com/bloer/bgexplorer-docker)
- Ben Loer [ben.loer@pnnl.gov](mailto:ben.loer@pnnl.gov)

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# Thank you

