



# Future Plans for Detector Materials Assay Program: Database and Simulation

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



# Introduction

- Designing and building a detector radioactively ‘clean’ requires considerable effort, must carefully control everything
- Good record keeping is essential
- Tools to manage and track this are now standard in dark matter/0nbb/low energy neutrino experiments
- PNNL has considerable experience supporting these efforts
- We are providing three tools to aid materials and assay work:
  - Radiopurity Database
  - Assay Manager (via the database)
  - Interpretation with Background Explorer

# Radiopurity.org Database

- Community tool used by several experiments
  - Originally from Berkeley and the AARM collaboration
  - Nuclear Instruments and Methods in Physics Research A 839 (2016) 6–11

- Three parts of the package:

- Material Assay Data Format (MADF)
  - ✓ Standardized, but flexible, json format
- Persephone
  - ✓ Open source format for storing, displaying and manipulating MADFs
  - ✓ CouchDB Database
  - ✓ <https://github.com/radiopurity/persephone>
- Public instance maintained by SNOLAB
  - ✓ <https://www.radiopurity.org/>
  - ✓ Can share results easily with community when ready

A database for storing the results of material radiopurity measurements

J.C. Loach<sup>a,b,\*</sup>, J. Cooley<sup>c</sup>, G.A. Cox<sup>d</sup>, Z. Li<sup>a</sup>, K.D. Nguyen<sup>b</sup>, A.W.P. Poon<sup>b</sup>

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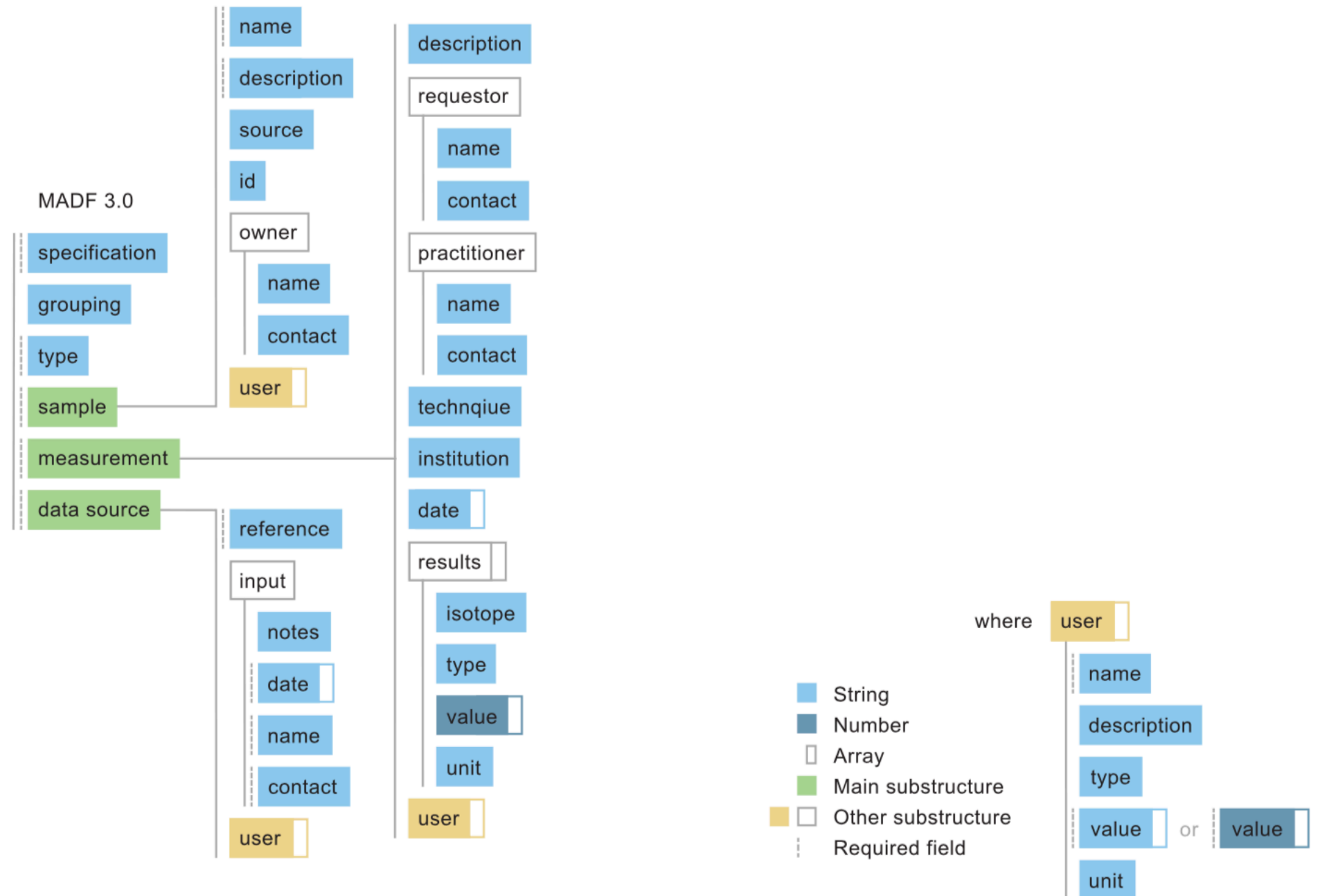
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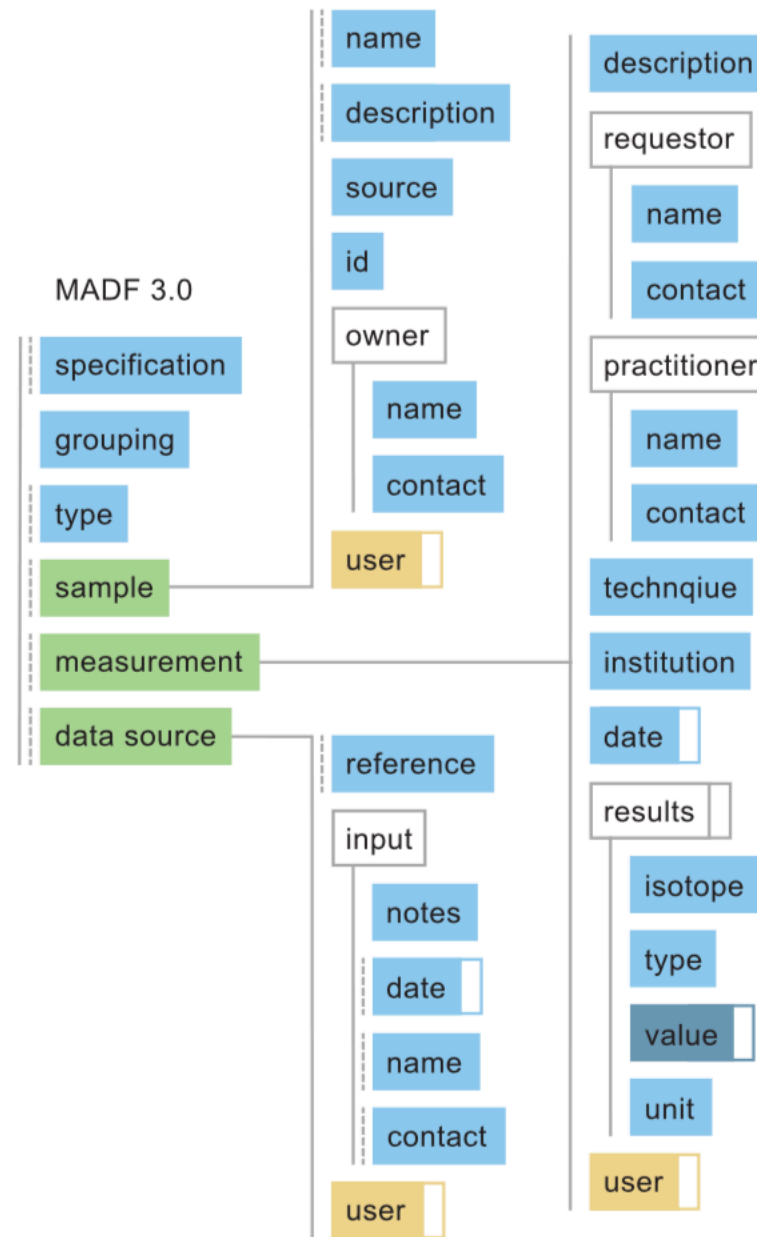
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No active support of radiopurity.org by original developers – problems with python versions and deprecated backend code.  
PNNL software engineer Elise Saxon developed new modern implementation of database in MongoDB

# Radiopurity.org Data Format



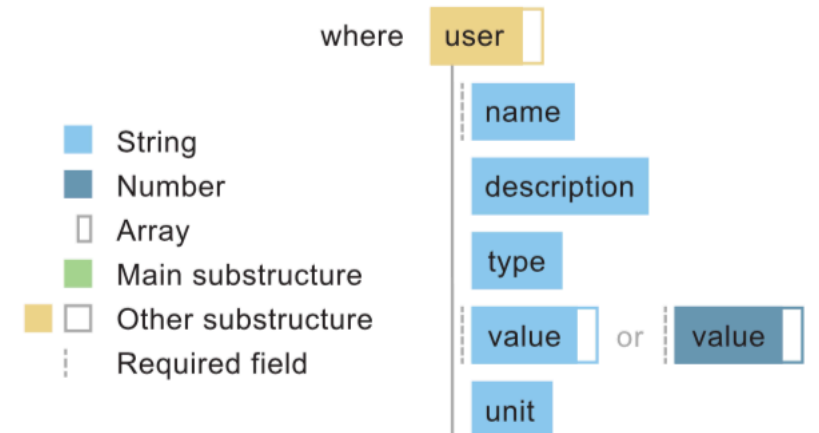
# Radiopurity.org Data Format



```

"results": [
  {
    "isotope": "U-238",
    "type": "measurement",
    "value": [400, 20],
    "unit": "ppb"
  },
  {
    "isotope": "Th-232",
    "type": "limit",
    "value": [100, 90],
    "unit": "ppt"
  }
]

```





## Query Assistant

this UI queries the radiopurity database

field: comparison: value:

grouping contains

AND OR add another query term

search

# Radiopurity2.0: Search



- ✓ grouping
- sample.name
- sample.description
- sample.source
- sample.id
- sample.owner.name
- sample.owner.contact
- measurement.results.isotope
- measurement.results.type
- measurement.results.unit
- measurement.results.value
- measurement.practitioner.name
- measurement.practitioner.contact
- measurement.technique
- measurement.institution
- measurement.date
- measurement.description
- measurement.requestor.name

UNDERGROUND  
EXPERIMENT



radiopurity.org

Query Assistant

Database

comparison:

value:

grouping

contains

AND OR add another query term

search

# Radiopurity2.0: Search



## Query Assistant

this UI queries the radiopurity database

field:  comparison:  value:

AND OR add another query term

search

- contains
- does not contain
- equals
- less than
- less than or equal to
- greater than
- greater than or equal to

# Radiopurity2.0: Search

## Query Assistant

this UI queries the radiopurity database

field:  comparison:  value:

AND OR add another query term

### FINAL QUERY

sample.name contains Copper

### RESULTS

num records: 86

name: Copper, Cuc2 Cylinder, CARLIER	grouping: ILIAS Edelweiss	Pb-214: 3mBq/kg Pb-210: 400mBq/kg Cs-137: 0.8mBq/kg K-40: 8mBq/kg Co-60: 1mBq/kg
name: Copper, Apical, cables	grouping: EDELWEISS (2011)	Ra-226: 26mBq/kg Th-228: 50mBq/kg Pb-210: 346mBq/kg K-40: 167mBq/kg Co-60: 25mBq/kg
name: Copper, NSOV, Norddeutsche Affinerie	grouping: EXO (2008)	K: 120ppb Th: 35ppt U: 63ppt
name: Copper, OFRP, Norddeutsche Affinerie	grouping: EXO (2008)	K: 55ppb Th: 2.4ppt U: 2.9ppt
name: Copper wire, McMaster-Carr	grouping: EXO (2008)	K: 1190ppb Th: 77ppt U: 270ppt Co-60: 0.23mBq/kg Cs-137: 1.5mBq/kg
name: Copper, OFHC	grouping: ILIAS ROSEBUD	Th-234: 100mBq/kg Pb-214: 2mBq/kg Bi-214: 2mBq/kg Ac-228: 0.5mBq/kg Pb-212: 2mBq/kg Tl-208: 0.5mBq/kg U-235: 3mBq/kg Cs-137: 0.2mBq/kg K-40: 4mBq/kg Co-60: 0.2mBq/kg
name: Copper, Cuc1 plate, VIGNON-CHOQUIT	grouping: ILIAS Edelweiss	Pb-214: 1mBq/kg Bi-214: 1mBq/kg Pb-212: 1mBq/kg Pb-210: 200mBq/kg K-40: 20mBq/kg Co-60: 2mBq/kg

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name: Copper, Cuc2 Cylinder, CARLIER	grouping: ILIAS Edelweiss	Pb-214: 3mBq/kg Pb-210: 400mBq/kg Cs-137: 0.8mBq/kg K-40: 8mBq/kg Co-60: 1mBq/kg
<p>database id: 5ef64bcb53b1687f92f7017c</p> <p>grouping: ILIAS Edelweiss</p> <p>sample info:</p> <p>name: Copper, Cuc2 Cylinder, CARLIER</p> <p>description: Copper, Cuc2 Cylinder, Batch Nr 6654, CARLIER</p> <p>source: CARLIER</p> <p>measurement info:</p> <p>technique: Ge</p> <p>institution: LSM</p> <p>measurement values:</p> <p>Pb-214 less than: 3 mBq/kg</p> <p>Pb-210 less than: 400 mBq/kg</p> <p>Cs-137 less than: 0.8 mBq/kg</p> <p>K-40 less than: 8 mBq/kg</p> <p>Co-60 less than: 1 mBq/kg</p> <p>data input: Ben Wise / James Loach contact: bwise@smu.edu / james.loach@gmail.com data input date: 2013-07-22</p> <p>measurement practitioner: C. Goldbach &amp; G. Nollez</p>		
name: Copper, Apical, cables	grouping: EDELWEISS (2011)	Ra-226: 26mBq/kg Th-228: 50mBq/kg Pb-210: 346mBq/kg K-40: 167mBq/kg Co-60: 25mBq/kg

# Radiopurity2.0: Search



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# Radiopurity2.0: Data Entry



## Insertion Assistant

### documents are inserted into the radiopurity database

experiment name or similar:

#### sample:

concise sample description:

detailed sample description:

where the sample came from:

sample identification number:

name of who owns the sample:

email or telephone of who owns the sample:

#### data source

reference for where the data came from:

name of the person/people who performed data input:

email or telephone of the person/people who performed data input:

data input date(s):  help: strings for dates of input (can be a range or a single date). NOTE: if entering a date range, separate date strings with a space.

data input notes (simplifications, assumptions):

#### measurement

name of who did the measurement:

email or telephone of who did the measurement:

measurement technique:

institution name:

measurement date(s):  help: strings for dates of measurement (can be a range or a single date). NOTE: if entering a date range, separate date strings with a space.

detailed measurement description:

name of who coordinated the measurement:

email or telephone of who coordinated the measurement:

#### measurement results

##### result

isotope:

measurement type:

units:

value(s):

if type is "measurement" this is the central value. If type is "limit" this is the upper limit. If type is "range" this is the lower bound.

if type is "measurement" this is the symmetric error. If type is "limit" this is the confidence level. If type is "range" this is the upper bound.

if type is "measurement" this is the asymmetric error. If type is "limit" no value is required. If type is "range" this is the confidence level.

add measurement result

insert

## Document Update Assistant

documents are updated in the radiopurity database

doc id: 5ef64bcb53b1687f92f7017c

remove entire document

grouping:  current value: ILIAS Edelweiss  remove

### sample:

sample name:  current value: Copper, Cuc2 Cylinder, CARLIER  remove

sample description:  current value: Copper, Cuc2 Cylinder, Batch Nr 6654, CARLIER  remove

sample source:  current value: CARLIER  remove

sample id:  current value: Gamma #46  remove

sample owner name:  current value:   remove

sample owner contact:  current value:   remove

### data input

data reference:  current value: ILIAS Database http://radiopurity.in2p3.fr/  remove

data input name:  current value: Ben Wise / James Loach  remove

data input contact:  current value: bwise@smu.edu / james.loach@gmail.com  remove

data input date:  NOTE: if entering a date range, separate date strings with a space. current value: 2013-07-22  remove all dates

data input notes:  current value:   remove

### measurement

measurement practitioner name:  current value: C. Goldbach & G. Nollez  remove

measurement practitioner contact:  current value:   remove

measurement technique:  current value: Ge  remove

measurement institution:  current value: LSM  remove

measurement date:  NOTE: if entering a date range, separate date strings with a space. current value:   remove all dates

measurement description:  current value:   remove

measurement requestor name:  current value:   remove

measurement requestor contact:  current value:   remove

### measurement results

#### result

isotope:  current value: Pb-214  remove

measurement type:  limit  remove

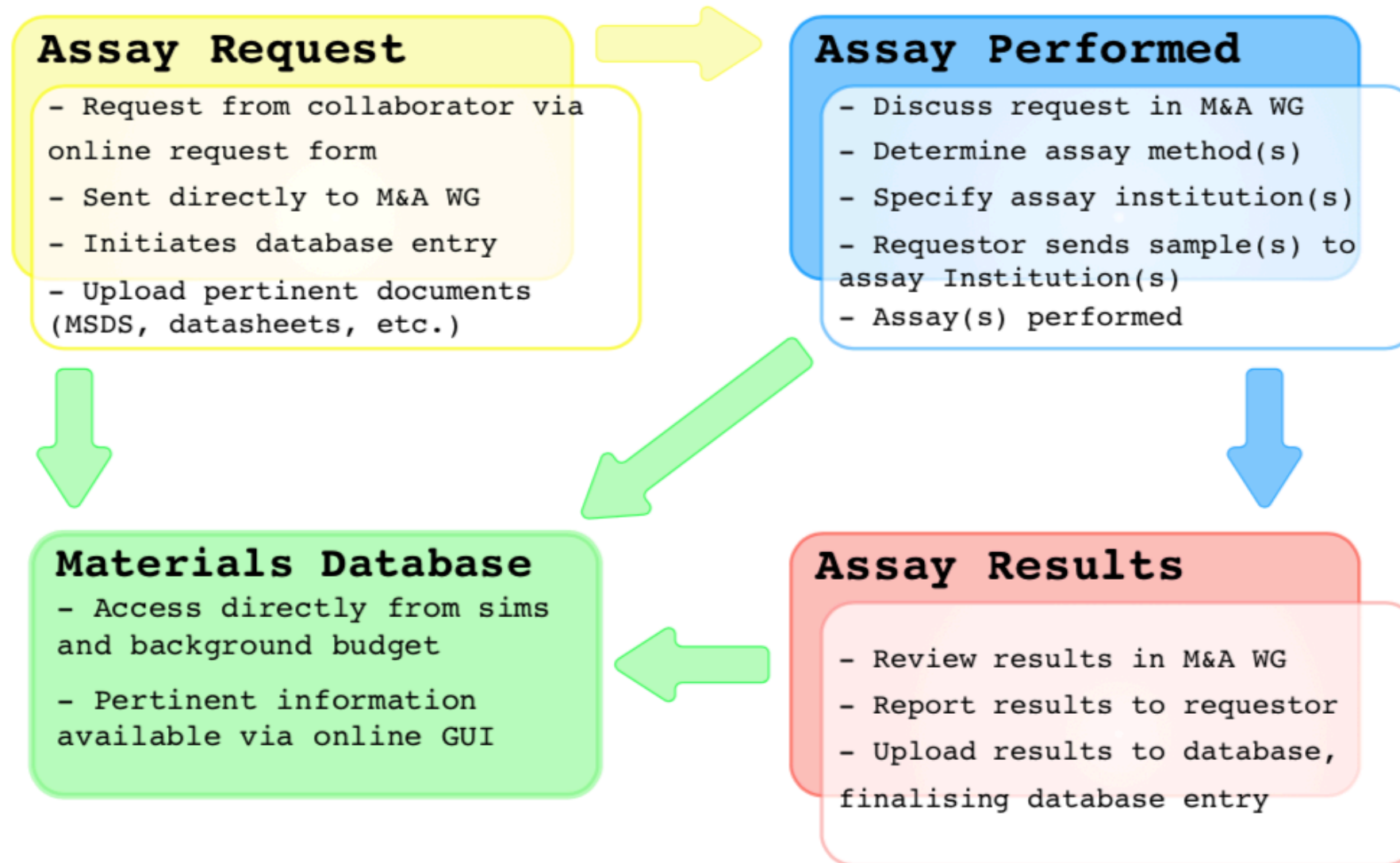
# Radiopurity2.0: Data Update

Previous versions of data entries maintained in 'old versions' database. Changes/deletions can be recovered

# DUNE Radiopurity Database Status

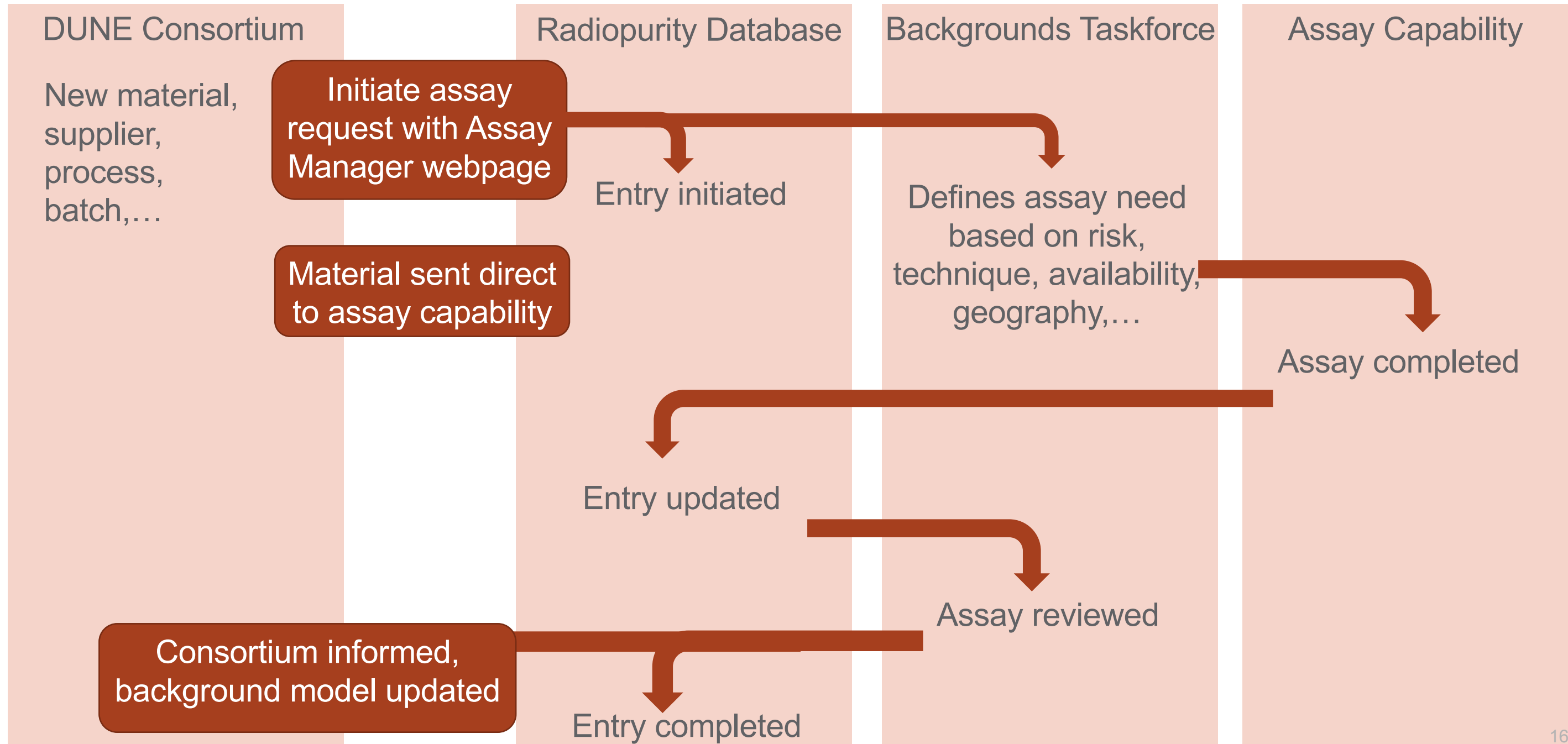
- New private radiopurity.org implementation complete
  - Final debugging
  - Data entry underway
- PNNL computer hosting database
- Expected to be available to collaboration within weeks
  
- Continued development planned
  - Working with SNOLAB and original developers to extend database capability
    - ✓ Move community installation to this version
    - ✓ Standardized data naming to aid searching
    - ✓ Measurement information (spectra, calibrations)
      - Aid distributed materials assays in large collaborations (ideal for DUNE)
    - ✓ ...

# Assay Management



- For DarkSide implemented a workflow for assay request management
- Centralized request form
- Interface with materials database
- M&A working group managed resources

# Assay Manager Workflow



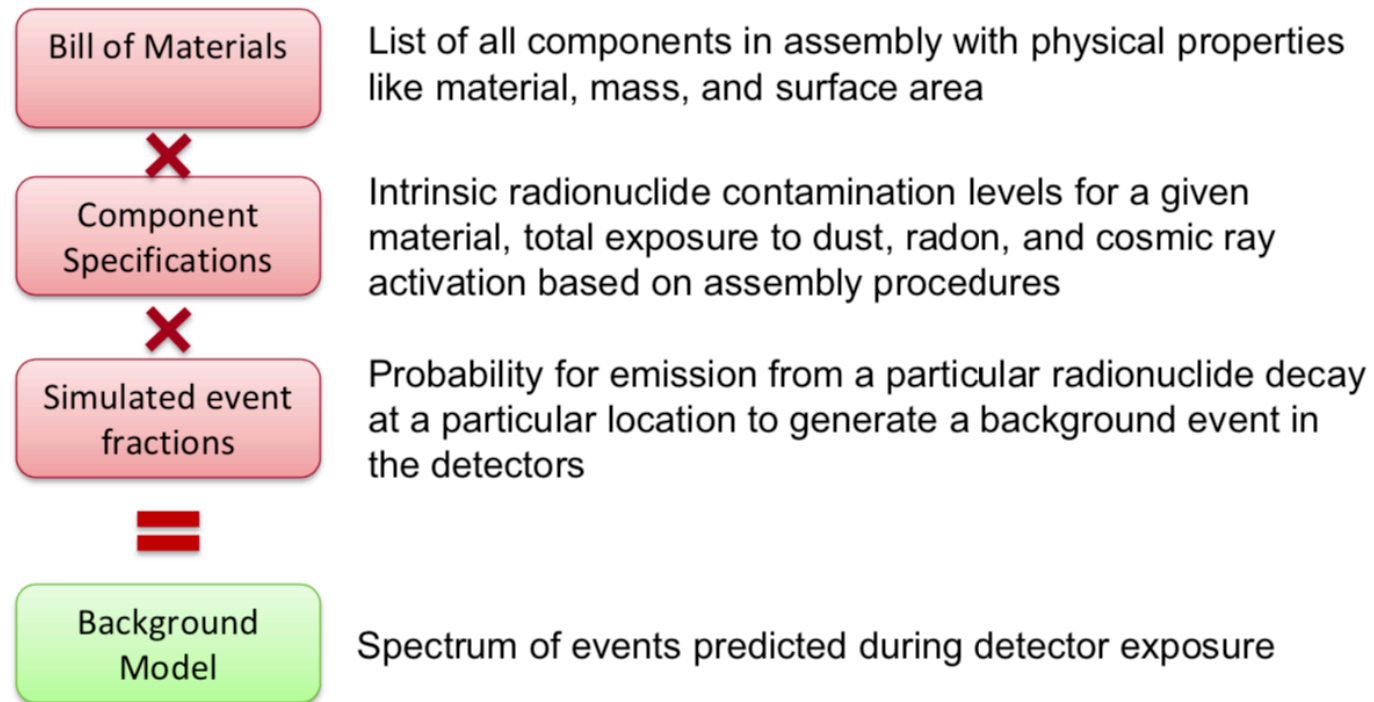


# Assay Manager Status

- Waiting for radiopurity database development to be completed
  - Creation of webpage request form on top of radiopurity.org
  - First version available within few months
- 
- Final workflow needs to be refined and approved by backgrounds taskforce

# Background Explorer

- Toolkit for modeling radioactive backgrounds
- Originally developed for SuperCDMS by Ben Loer



e.g.:

2 kg component

×

1 mBq(U238) / kg

×

$10^{-3}$  cts/kg/keV  
per U238 decay

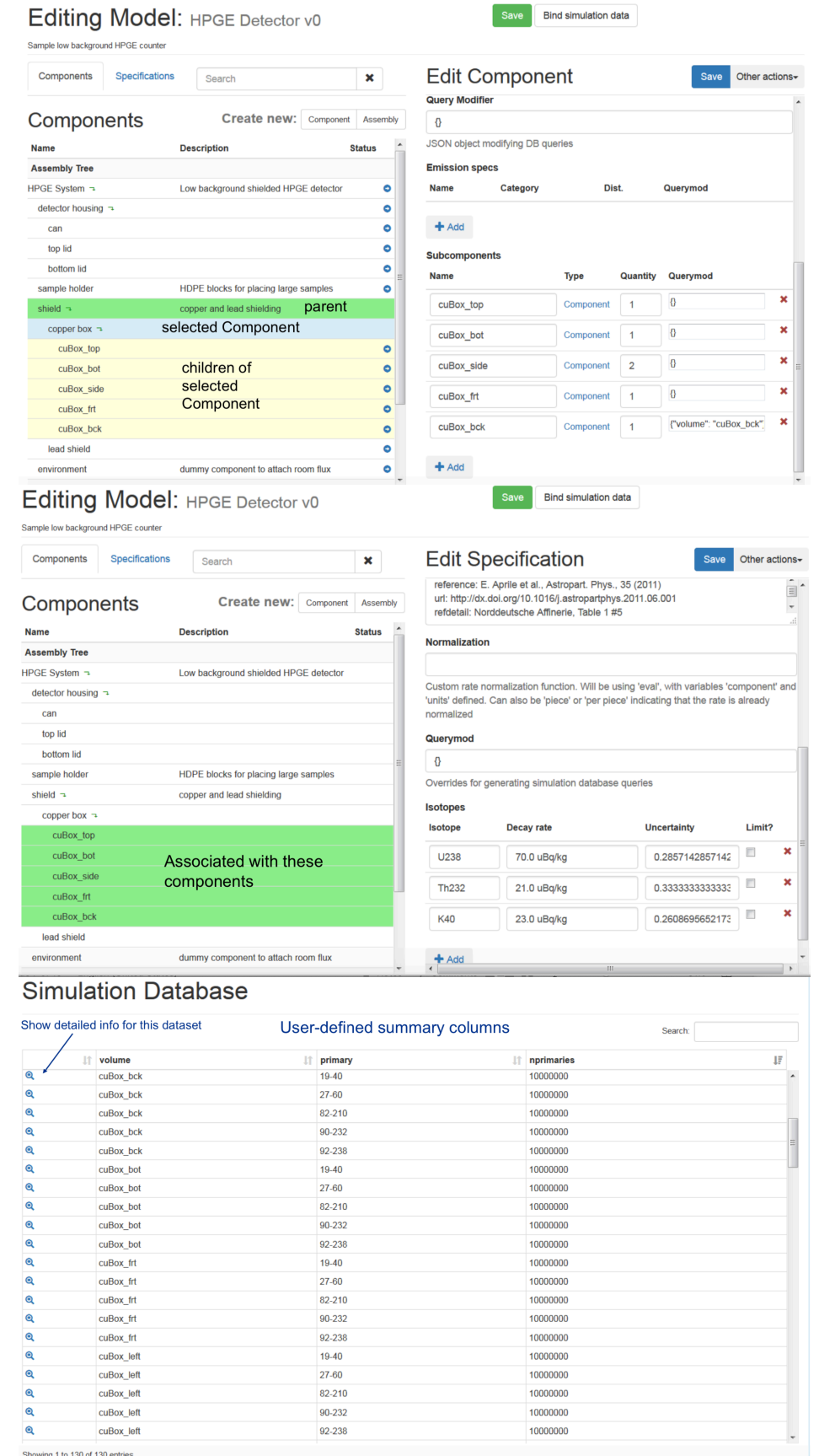
=

~0.2 dru (cts/kg/keV/day)

<https://github.com/bloer/bgexplorer-demo>

# Background Explorer

- Define the detector model
  - Hierarchy of components placed in assemblies
- Define radioactive sources
  - Bulk (normalized by mass or volume), surface (normalized by area)
  - RadioactiveContam: Directly defined bulk or surface rate. Accepts error bars and limits
  - RadonExposure (estimates surface Pb210 based on exposure time and radon air levels); CosmogenicActivation (estimates bulk nuclides from cosmic ray exposure, based on exposure time and activation rates)
- Define simulation efficiencies
  - Match simulation datasets to components and convert to requested value type (e.g. average rate or spectra)
  - Customizable to data format (everything from mysql to directory of ROOT files)
  - Tracks uncertainties from assay and simulation



The screenshot displays the 'Editing Model: HPGE Detector v0' interface, which is divided into several panels:

- Components Panel:** Shows an assembly tree for the 'HPGE System'. The 'shield' component is highlighted in green and labeled as the 'parent'. Below it, the 'copper box' components (cuBox\_top, cuBox\_bot, cuBox\_side, cuBox\_frt, cuBox\_bck) are highlighted in yellow and labeled as 'children of selected Component'.
- Edit Component Panel:** Shows the configuration for a selected component, including 'Query Modifier' (JSON object), 'Emission specs' table, and 'Subcomponents' table.
- Edit Specification Panel:** Shows the configuration for a selected specification, including 'Normalization' (custom rate function), 'Querymod' (overrides for simulation queries), and 'Isotopes' table.
- Simulation Database Panel:** Shows a table of simulation datasets with columns for volume, primary, and nprimaries. A search bar and 'User-defined summary columns' are also visible.

Name	Category	Dist.	Querymod
cuBox_top	Component	1	0
cuBox_bot	Component	1	0
cuBox_side	Component	2	0
cuBox_frt	Component	1	0
cuBox_bck	Component	1	["volume", "cuBox_bck"]

Isotope	Decay rate	Uncertainty	Limit?
U238	70.0 uBq/kg	0.2857142857142	<input checked="" type="checkbox"/>
Th232	21.0 uBq/kg	0.3333333333333	<input checked="" type="checkbox"/>
K40	23.0 uBq/kg	0.2608695652174	<input checked="" type="checkbox"/>

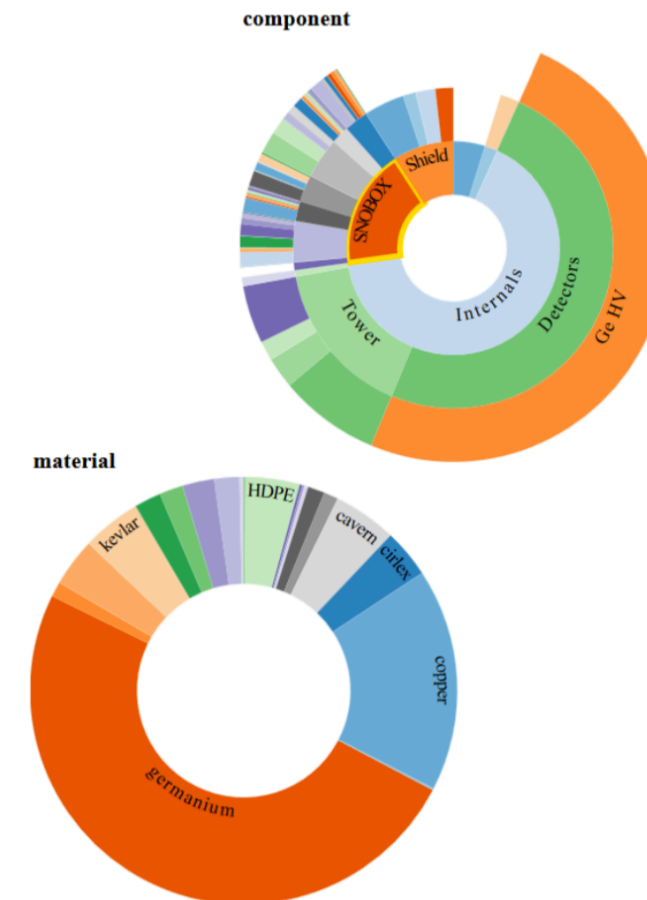
Volume	Primary	nprimaries
cuBox_bck	19-40	10000000
cuBox_bck	27-60	10000000
cuBox_bck	82-210	10000000
cuBox_bck	90-232	10000000
cuBox_bck	92-238	10000000
cuBox_bot	19-40	10000000
cuBox_bot	27-60	10000000
cuBox_bot	82-210	10000000
cuBox_bot	90-232	10000000
cuBox_bot	92-238	10000000
cuBox_frt	19-40	10000000
cuBox_frt	27-60	10000000
cuBox_frt	82-210	10000000
cuBox_frt	90-232	10000000
cuBox_frt	92-238	10000000
cuBox_left	19-40	10000000
cuBox_left	27-60	10000000
cuBox_left	82-210	10000000
cuBox_left	90-232	10000000
cuBox_left	92-238	10000000

# Background Explorer

- Inspect the results
  - Generate overview tables sorted by component, emission spectra, or simulation data
  - Detail page for each element with links to other associated elements
  - Rate results sorted into tables with expandable categories and zoomable charts
  - Hooks to display custom pages

Predicted rates in counts / kg\*keVr\*year

Category	Ge HV ERsingles	Si HV ERsingles	Ge iZIP ERsingles	Si iZIP ERsingles	Ge iZIP NRsingles (x10 <sup>-6</sup> )	Si iZIP NRsingles (x10 <sup>-6</sup> )
<b>Total</b>	<b>48.</b>	<b>360.</b>	<b>50.</b>	<b>400.</b>	<b>3200.</b>	<b>2300.</b>
<b>Coherent Neutrinos</b>					2300.	1600.
<b>-Detector Internal Contamination</b>	24.	280.	4.7	250.	0	0
Tritium	24.	33.	4.7	6.6	0	0
Silicon-32	0	250.	0	250.	0	0
Other						
<b>-Material Internal Contamination</b>	17.	66.	36.	120.	370.	460.
+Housing and Towers	6.5	34.	19.	65.	51.	66.
+Readout Cables	0.31	0.46	0.39	0.80	11.	15.
+SNOBOX Cans	4.0	13.	6.5	22.	68.	75.
Kevlar Ropes	2.1	5.1	2.7	8.3	3.6	4.0
+Calibration	0.92	3.0	1.2	3.6	0.05	0.05
+Shield Materials	3.5	10.	5.3	17.	240.	300.
Bulk Pb-210 in Lead	0.07	0	0.22	0.75		
<b>-Material Internal Activation</b>	2.3	8.4	3.9	13.		
Housing and Towers	0.64	2.5	1.0	4.1		
+SNOBOX	1.5	5.6	2.8	8.9		
Shield	0.07	0.28	0.14	0.41		
Other						
<b>+Non-line-of-sight Surfaces</b>	1.6	5.0	2.9	9.3	35.	41.
<b>Prompt Interstitial Radon</b>	0.61	1.8	0.87	2.7		
<b>+Cavern Environment</b>	2.3	3.5	2.0	9.6	330.	160.
<b>Cosmic Ray Flux</b>	0.00	0.00	0.00	0.00	85.	99.



# Background Explorer Status

- Skeleton model implemented on PNNL machine
- Summer intern Sylvia Munson making first simulations to populate model
- Plans to make version 1 available to collaboration in ~2 months
- Further development:
  - Could be repository of official simulation campaign (e.g. USussex and SDSMT work)
  - Additional detail and components
  - Other backgrounds (alphas, gammas)

## Components

Name

DUNE\_SP (assemblyroot)

Target

Argon

APA

CPA

Cryostat

I-Beams

Warm skin

Foam Insulation

Wood Insulation

Coldskin



# Conclusions

- Materials and assay management tools under development for DUNE
  - Radiopurity.org database
    - ✓ Ready within weeks
  - Material and assay request management
    - ✓ Ready within months
  - Background explorer
    - ✓ 1<sup>st</sup> version ready within months
- Will aid background control for DUNE
- Essential groundwork for a low background module
  - See discussion tomorrow



**Pacific  
Northwest**  
NATIONAL LABORATORY

**Thank you**