Sample directory:
/disk/bulk_atp/gator/Sample_Sim_and_Analysis_Results/Rerun_15xR11410

========= Simulation input =========
(See geometry below)
gatordir="/disk/bulk_atp/gator/"
binary="/disk/bulk_atp/gator//simulations/gator_v2.0/bin/Linux-g++/gator_1.2"
datadir="/disk/bulk_atp/gator//Sample_Sim_and_Analysis_Results"
sample="Rerun_15xR11410"
queue="5:00:00"
maxnodes=100
totevents= 10000000
n_beamOn= 100000
isotope_list=["238U","232Th","40K","60Co","137Cs","226Ra","235U","228Th"]

========= Line efficiency =========
See values in Table 1.

========= Livetime and inputs for the analysis =========

Measure life time: 1.944e+06 s = 22.5 d
Background life time: 2.808e+06 s = 32.5 d

Background folder: /disk/bulk_atp/gator/background/Background_PMTs_PTFE_holders
Calibration folder: /disk/bulk_atp/gator/Calibrations/2015.08.07
Amount of material (kg or pieces): 15

=== List of SPE files used for the analysis ===
PMT_Batch_20_0_006.SPE
PMT_Batch_20_0_007.SPE
PMT_Batch_20_0_008.SPE
PMT_Batch_20_0_009.SPE
PMT_Batch_20_0_010.SPE
PMT_Batch_20_0_011.SPE
PMT_Batch_20_0_012.SPE
PMT_Batch_20_0_013.SPE
PMT_Batch_20_0_014.SPE
PMT_Batch_20_0_015.SPE
PMT_Batch_20_0_016.SPE
PMT_Batch_20_0_017.SPE
PMT_Batch_20_0_018.SPE
PMT_Batch_20_0_019.SPE
PMT_Batch_20_0_020.SPE
PMT_Batch_20_0_021.SPE
PMT_Batch_20_0_022.SPE
PMT_Batch_20_0_023.SPE
PMT_Batch_20_0_024.SPE
PMT_Batch_20_0_025.SPE
PMT_Batch_20_0_026.SPE
PMT_Batch_20_0_027.SPE
PMT_Batch_20_0_028.SPE
PMT_Batch_20_0_029.SPE
PMT_Batch_20_0_030.SPE
PMT_Batch_20_0_031.SPE
PMT_Batch_20_0_032.SPE
PMT_Batch_20_0_033.SPE
PMT_Batch_20_0_034.SPE
PMT_Batch_20_0_035.SPE
PMT_Batch_20_0_036.SPE
PMT_Batch_20_0_037.SPE
PMT_Batch_20_0_038.SPE
PMT_Batch_20_0_039.SPE
PMT_Batch_20_0_040.SPE

PMT_Batch_20_0_041.SPE
PMT_Batch_20_0_042.SPE
PMT_Batch_20_0_043.SPE
PMT_Batch_20_0_044.SPE
PMT_Batch_20_0_045.SPE
PMT_Batch_20_0_046.SPE
PMT_Batch_20_0_047.SPE
PMT_Batch_20_0_048.SPE
PMT_Batch_20_0_049.SPE
PMT_Batch_20_0_050.SPE

=== List of SPE files excluded from the analysis ===
PMT_Batch_20_0_000.SPE
PMT_Batch_20_0_001.SPE
PMT_Batch_20_0_002.SPE
PMT_Batch_20_0_003.SPE
PMT_Batch_20_0_004.SPE
PMT_Batch_20_0_005.SPE
PMT_Batch_20_0_051.SPE
PMT_Batch_20_0_052.SPE

========= Geometry of the sample =========
See figure of the geometry below.
The .wrl file is also saved in the sample directory. And the dimensions/material and position are specified in the code below.

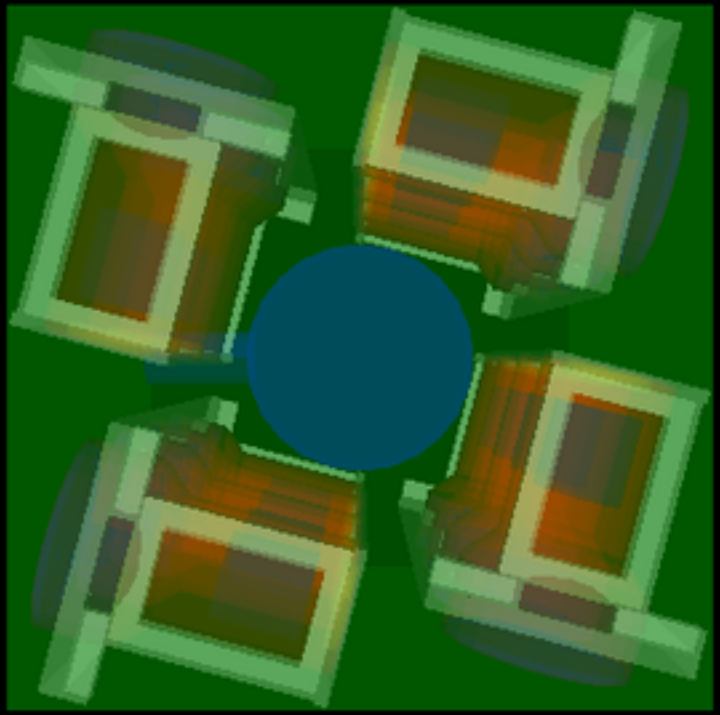
---------- icc file code ----------

```
////////////////////////////////////////////////////////////////////////
// This file is the only one needed to include in the GeConstruction
// At line 48 specify the number of PMTs to include in the simulation
// Lines 57 to 70 construct each PTFE holder. Set to "false" if the holder is not in place
// If the holder is not contructed, the PMTs designated to that holder will not be constructed, regardless of the number specified at line 45
// a single PMT on the endcap is at line 112
// For just one PMT on the endcap, for example, set all holders to false and uncomment the last line in this file.
////////////////////////////////////////////////////////////////////////


G4double PMTsZoffset=43*mm; //Vertical Offset of the lowest PMT
G4double PMTsSpacing=80*mm; //Distance between the PMTs central axis
G4double PMTlenght = 114*mm;


// front plate
G4double HolderWidth=100*mm;
G4double HolderLenght=97*mm;
G4double HolderHeight_short=246*mm, HolderHeight_long=326*mm;

G4LogicalVolume* HolderLong_log = ConstructPMTholder_long();
G4LogicalVolume* HolderShort_log = ConstructPMTholder_short();
G4LogicalVolume* PMTR11410_log = ConstructPmtR11410();

std::vector<G4VPhysicalVolume*>* PMTs_vec = new
std::vector<G4VPhysicalVolume*>();

G4double PMT1stColX=(114.5)*mm, PMT1stColY=(67.5)*mm, PMT1stColZ=PMTsZoffset-cavity1_z/2.;

G4ThreeVector PMT_VertStep(0.*mm,0.*mm,PMTsSpacing); //Distance between the PMTs central axis
```

```
G4ThreeVector PMT1stCol_offset((114.5)*mm,(67.5)*mm,PMTsZoffset-cavity1_z/2.);
G4ThreeVector PMT2ndCol_offset((67.5)*mm,-(114.5)*mm,PMTsZoffset-cavity1_z/2.);
G4ThreeVector PMT3rdCol_offset(-(114.5)*mm,-(67.5)*mm,PMTsZoffset-cavity1_z/2.);
G4ThreeVector
PMT4thCol_offset(-(67.5)*mm,(114.5)*mm,PMTsZoffset-(cavity1_z/2.)+80*mm); //The
short column (80mm = teflon table height)

G4RotationMatrix PMT1stCol_rot, PMT2ndCol_rot, PMT3rdCol_rot, PMT4thCol_rot;
PMT1stCol_rot.rotateY(-90.*deg);
PMT1stCol_rot.rotateZ(-15.*deg);
PMT2ndCol_rot.rotateX(-90.*deg);
PMT2ndCol_rot.rotateZ(-15.*deg);
PMT3rdCol_rot.rotateY(90.*deg);
PMT3rdCol_rot.rotateZ(-15.*deg);
PMT4thCol_rot.rotateX(90.*deg);
PMT4thCol_rot.rotateZ(-15.*deg);

G4ThreeVector PMTpos;
std::stringstream PMTVolName;


//
// # PMTs
for(G4int i=1; i<16; i++){
//    char index[100]="";
      PMTVolName.str("");
//    sprintf(index,"%d",i);
      PMTVolName <<"PMT"<<i<<"_phys";
//    G4cout << "PMT: "<< i << G4endl;
      G4cout << PMTVolName.str() << G4endl;

/*
// below rewritten for 9 PMTs (2,2,2, & 3 in each holder).
      if(i<=3){
            PMTpos = PMT1stCol_offset + ((i-1)%4)*PMT_VertStep;
            if(true) PMTs_vec -> push_back(new
G4PVPlacement(G4Transform3D(PMT1stCol_rot,PMTpos),PMTR11410_log,PMTVolName.str()
,cavity1_log,false,0));
      }else if(3<i && i<=5){
            PMTpos = PMT2ndCol_offset + ((i-1)%4)*PMT_VertStep;
            if(true) PMTs_vec -> push_back(new
G4PVPlacement(G4Transform3D(PMT2ndCol_rot,PMTpos),PMTR11410_log,PMTVolName.str()
,cavity1_log,false,0));
      }else if(5<i && i<=7){
            PMTpos = PMT3rdCol_offset + ((i-1)%4)*PMT_VertStep;
            if(true) PMTs_vec -> push_back(new
G4PVPlacement(G4Transform3D(PMT3rdCol_rot,PMTpos),PMTR11410_log,PMTVolName.str()
,cavity1_log,false,0));
      }else if(7<i && i<=9){
            PMTpos = PMT4thCol_offset + ((i-1)%4)*PMT_VertStep;
            if(true) PMTs_vec -> push_back(new
G4PVPlacement(G4Transform3D(PMT4thCol_rot,PMTpos),PMTR11410_log,PMTVolName.str()
,cavity1_log,false,0));
      }
*/


// below constructs PMTs into each PMT holder. Set if(true) to (false) if the
PMT holders and PMTs are not in the cavity
      if(i<=4){
            PMTpos = PMT1stCol_offset + ((i-1)%4)*PMT_VertStep;
            if(true) PMTs_vec -> push_back(new
G4PVPlacement(G4Transform3D(PMT1stCol_rot,PMTpos),PMTR11410_log,PMTVolName.str()
,cavity1_log,false,0));
```

```
      }else if(4<i && i<=8){
            PMTpos = PMT2ndCol_offset + ((i-1)%4)*PMT_VertStep;
            if(true) PMTs_vec -> push_back(new
G4PVPlacement(G4Transform3D(PMT2ndCol_rot,PMTpos),PMTR11410_log,PMTVolName.str()
,cavity1_log,false,0));
      }else if(8<i && i<=12){
            PMTpos = PMT3rdCol_offset + ((i-1)%4)*PMT_VertStep;
            if(true) PMTs_vec -> push_back(new
G4PVPlacement(G4Transform3D(PMT3rdCol_rot,PMTpos),PMTR11410_log,PMTVolName.str()
,cavity1_log,false,0));
      }else if(12<i && i<=15){
            PMTpos = PMT4thCol_offset + ((i-1)%4)*PMT_VertStep;
            if(true) PMTs_vec -> push_back(new
G4PVPlacement(G4Transform3D(PMT4thCol_rot,PMTpos),PMTR11410_log,PMTVolName.str()
,cavity1_log,false,0));
      }


}



G4double HolderHrzOffset = HolderLenght-PMTlenght;
G4double cos15 = TMath::Cos(15*TMath::Pi()/180);
G4double sin15 = TMath::Sin(15*TMath::Pi()/180);

G4RotationMatrix Holder1_rot;
Holder1_rot.rotateZ(75.*deg);

G4ThreeVector Holder1pos(114.5*mm+HolderHrzOffset*cos15,67.5*mm-
HolderHrzOffset*sin15,(HolderHeight_long-cavity1_z)/2.);


// comment out below if holder is not in use
G4VPhysicalVolume* Holder1_phys = new
G4PVPlacement(G4Transform3D(Holder1_rot,Holder1pos),HolderLong_log,"Holder1_phys
",cavity1_log,false,0,true);


G4RotationMatrix Holder2_rot;
Holder2_rot.rotateZ(-15.*deg);

G4ThreeVector Holder2pos(67.5*mm-HolderHrzOffset*sin15,-114.5*mm-
HolderHrzOffset*cos15,(HolderHeight_long-cavity1_z)/2.);


// comment out below if holder is not in use
G4VPhysicalVolume* Holder2_phys = new
G4PVPlacement(G4Transform3D(Holder2_rot,Holder2pos),HolderLong_log,"Holder2_phys
",cavity1_log,false,0,true);


G4RotationMatrix Holder3_rot;
Holder3_rot.rotateZ(-105.*deg);

G4ThreeVector Holder3pos(-114.5*mm-HolderHrzOffset*cos15,-
67.5*mm+HolderHrzOffset*sin15,(HolderHeight_long-cavity1_z)/2.);


// comment out below if holder is not in use
G4VPhysicalVolume* Holder3_phys = new
G4PVPlacement(G4Transform3D(Holder3_rot,Holder3pos),HolderLong_log,"Holder3_phys
",cavity1_log,false,0,true);
```

```
G4RotationMatrix Holder4_rot;
Holder4_rot.rotateZ(-195.*deg);

G4ThreeVector Holder4pos(-
67.5*mm+HolderHrzOffset*sin15,114.5*mm+HolderHrzOffset*cos15,
(HolderHeight_short-cavity1_z)/2.+80*mm); //The short column (80mm = teflon
table height)


// comment out below if holder is not in use
G4VPhysicalVolume* Holder4_phys = new
G4PVPlacement(G4Transform3D(Holder4_rot,Holder4pos),HolderShort_log,"Holder4_phy
s",cavity1_log,false,0,true);


//--- A PMT on top of the end-cap as the 16th PMT ---\\
//G4VPhysicalVolume* PMT_envel_phys16 = new G4PVPlacement(0,endcap_Shift +
G4ThreeVector(0.,0.,endcapHeight1/2.+(1*mm)),PMTR11410_log,"PMTonTop",
cavity1_log, false, 0,true);
```

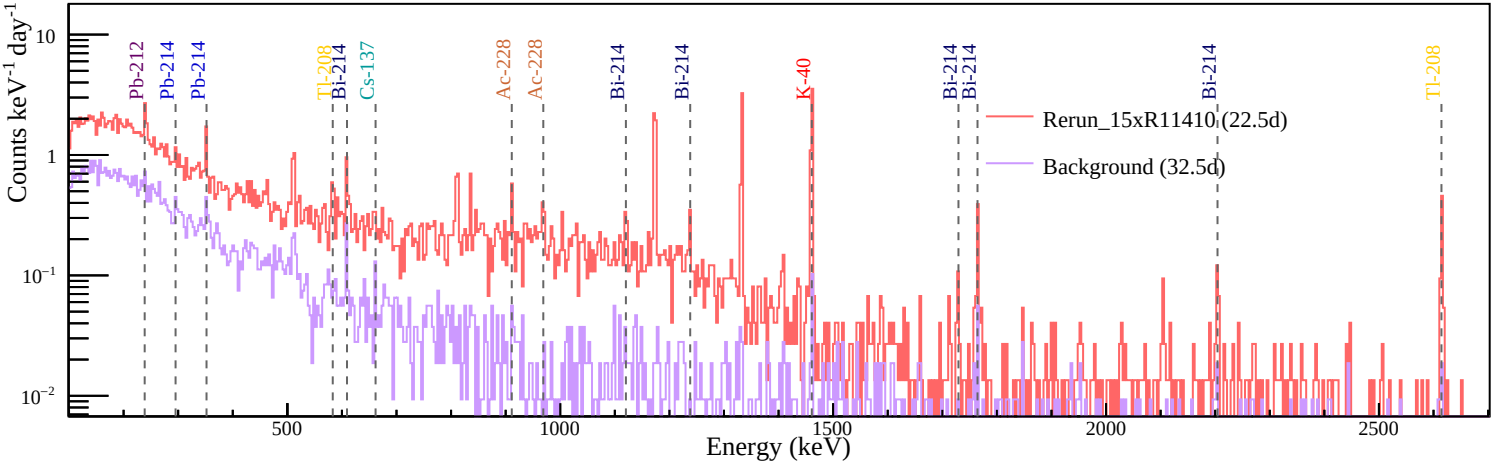


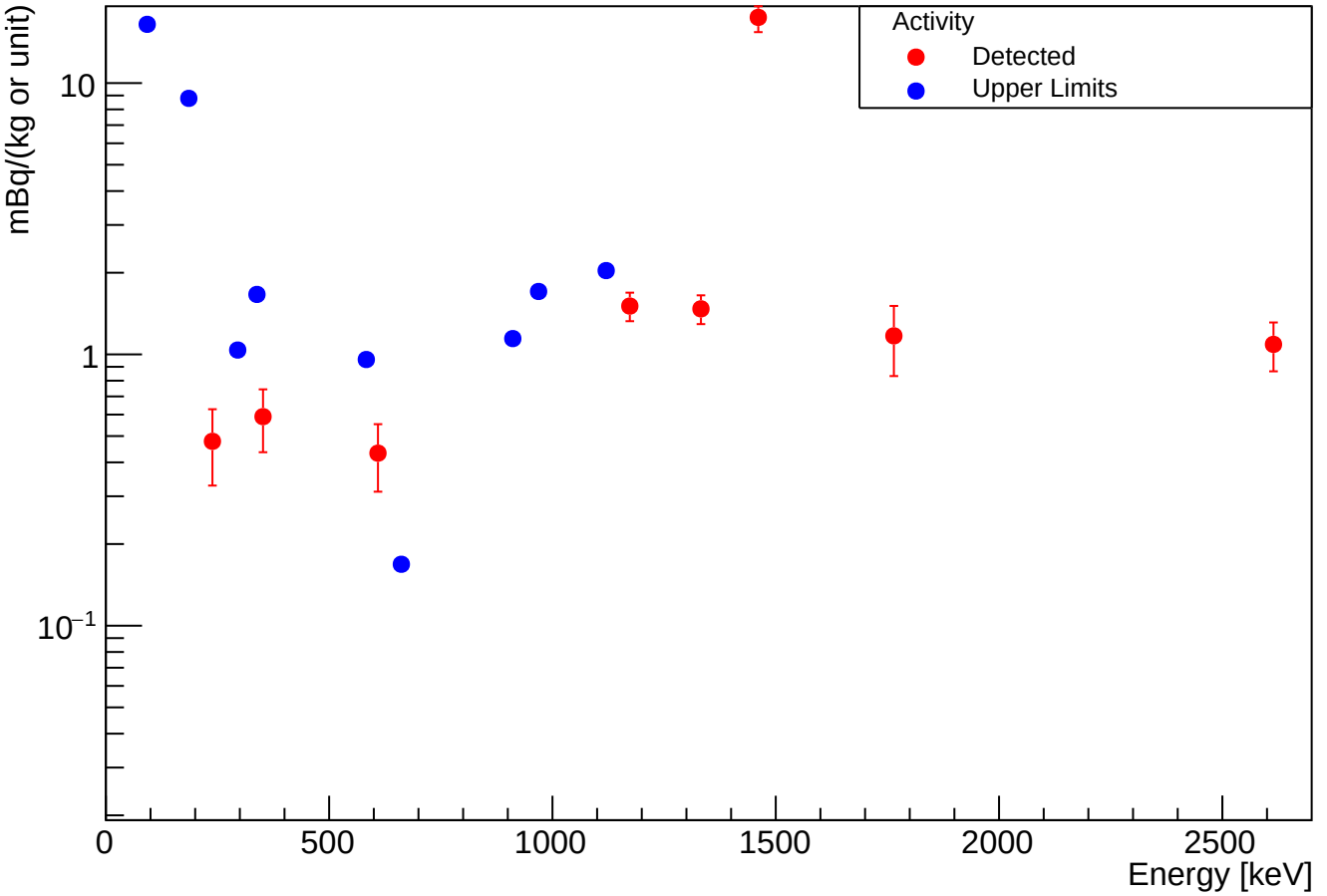
Isotope	Energy (keV)	Line BR	Effic	BRxEffic
^{234}Th	92.6	0.0433	0.00354	0.000153
^{235}U	185.72	0.572	0.000552	0.000316
^{212}Pb	238.632	0.436	0.0104	0.00453
^{214}Pb	295.224	0.184	0.0104	0.00191
^{228}Ac	338.32	0.114	0.0104	0.00118
^{214}Pb	351.932	0.356	0.00999	0.00356
^{208}Tl	583.187	0.3054	0.00765	0.00234
^{214}Bi	609.312	0.4549	0.00758	0.00345
^{137}Cs	661.657	0.8499	0.00809	0.00688
^{228}Ac	911.196	0.262	0.00620	0.00162
^{228}Ac	968.96	0.159	0.00620	0.000986
^{214}Bi	1120.29	0.1491	0.00562	0.000838
^{60}Co	1173.23	0.9985	0.00612	0.00611
^{60}Co	1332.49	0.9998	0.00580	0.00580
^{40}K	1460.88	0.1055	0.00569	0.000600
^{214}Bi	1764.49	0.1531	0.00470	0.000719
^{208}Tl	2614.51	0.3584	0.00348	0.00125

Table 1: Efficiency Table, as calculated by the simulation.

Isotope	E(keV)	PeakCnts	CompCnts	BkCnts	isBkdet	LineCnts	LdCnts	LdActiv	Activity (mBq/u.)
^{234}Th	92.6	94.0 +- 9.7	74.7 +- 8.7	2.7 +- 6.6	T	17 +- 15	51.3	12.7	< 16.5
^{235}U	185.72	141 +- 12	112 +- 11	17.9 +- 8.0	T	11 +- 18	63.3	7.64	< 8.78
^{212}Pb	238.632	188 +- 14	105 +- 10	20.4 +- 7.5	T	63 +- 19	61.4	0.516	0.48 +- 0.15
^{214}Pb	295.224	76.5 +- 8.8	61.3 +- 7.9	10.9 +- 6.0	T	4 +- 13	48.1	0.959	< 1.04
^{228}Ac	338.32	58.2 +- 7.7	45.8 +- 6.8	-2.9 +- 5.3	T	12 +- 12	40.4	1.30	< 1.66
^{214}Pb	351.932	124 +- 11	52.1 +- 7.3	11.0 +- 6.2	T	61 +- 15	45.9	0.492	0.59 +- 0.15
^{208}Tl	583.187	61.3 +- 7.9	26.9 +- 5.3	4.3 +- 2.9	T	30.2 +- 9.9	31.5	0.515	< 0.957
^{214}Bi	609.312	85.0 +- 9.3	22.0 +- 4.8	19.5 +- 4.4	T	43 +- 11	34.7	0.383	0.43 +- 0.12
^{137}Cs	661.657	29.3 +- 5.5	20.3 +- 4.6	8.3 +- 3.1	T	0.7 +- 7.8	29.8	0.165	< 0.168
^{228}Ac	911.196	46.5 +- 6.9	19.5 +- 4.5	3.4 +- 2.4	T	23.7 +- 8.6	27.4	0.643	< 1.14
^{228}Ac	968.96	41.3 +- 6.5	22.0 +- 4.8	-0.7 +- 1.5	T	19.2 +- 8.2	26.8	1.04	< 1.71
^{214}Bi	1120.29	40.8 +- 6.5	16.8 +- 4.2	2.8 +- 2.2	T	21.2 +- 8.0	25.7	1.17	< 2.04
^{60}Co	1173.23	295 +- 17	25.3 +- 5.1	1.4 +- 1.7	T	269 +- 18	29.0	0.181	1.51 +- 0.18
^{60}Co	1332.49	270 +- 16	19.0 +- 4.5	2.1 +- 2.1	T	249 +- 17	26.5	0.174	1.47 +- 0.18
^{40}K	1460.88	332 +- 18	17.6 +- 4.3	9.0 +- 2.7	T	306 +- 19	28.2	1.79	17.5 +- 2.1
^{214}Bi	1764.49	33.0 +- 5.8	5.0 +- 2.4	3.5 +- 2.1	T	24.5 +- 6.7	18.4	0.978	1.17 +- 0.34
^{208}Tl	2614.51	43.0 +- 6.6	2.0 +- 1.7	1.4 +- 1.7	T	39.6 +- 7.1	14.3	0.436	1.09 +- 0.22

Table 2: Activity Table, as calculated by the analysis code and given per unit, as indicated in the analysis input. Limits are given at 95CL, activities at one sigma.


Counts keV^{-1} day^{-1}
10
1
10^{-1}
10^{-2}
Pb-212
Pb-214
Pb-214
Tl-208
Bi-214
Cs-137
Ac-228
Ac-228
Bi-214
Bi-214
K-40
Bi-214
Bi-214
Bi-214
Tl-208
Rerun_15xR11410 (22.5d)
Background (32.5d)
500
1000
1500
2000
2500
Energy (keV)


Activity
Detected
Upper Limits
mBq/(kg or unit)
10
1
10^{-1}
0
500
1000
1500
2000
2500
Energy [keV]