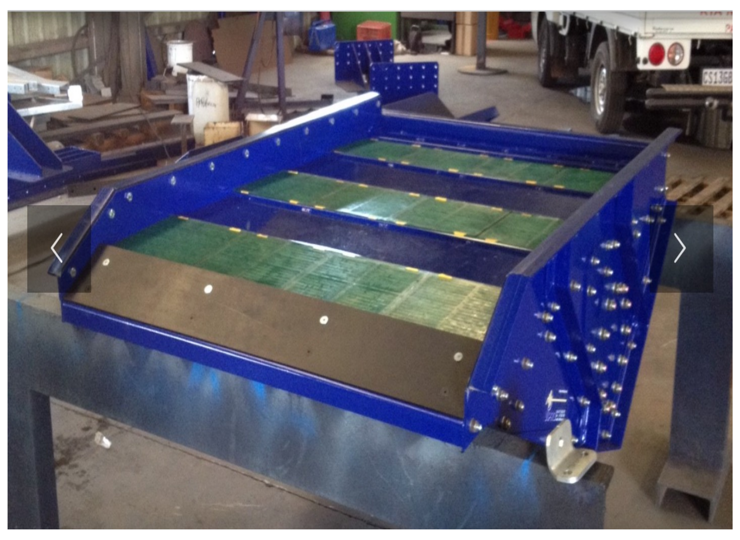
Nuclear-Medical Technique in 4IR Diamond Mining

G. Bentum[1], T. Nemakhavhani[2], M. Cook[2], SH Connell[1]

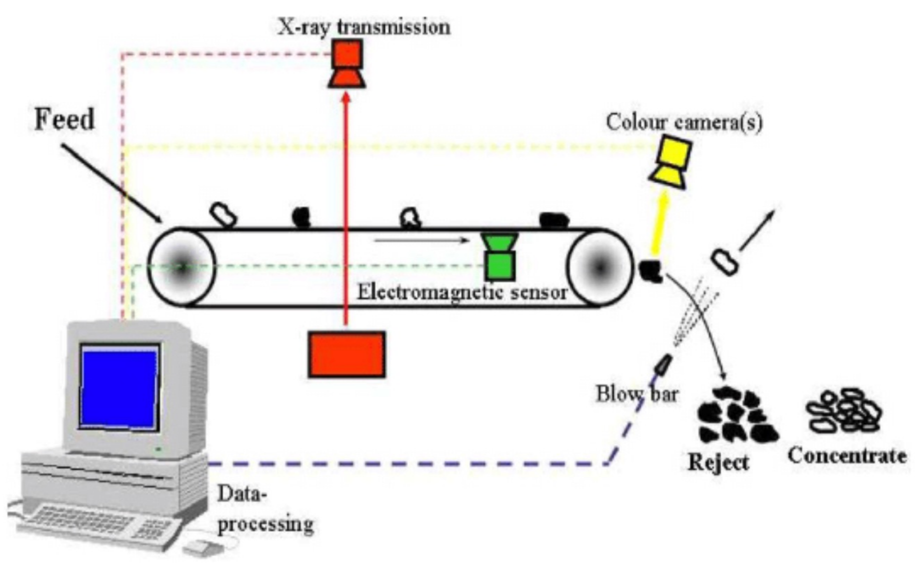
1. University of Johannesburg, Johannesburg, South Africa

What is this poster about?

Grease Tables

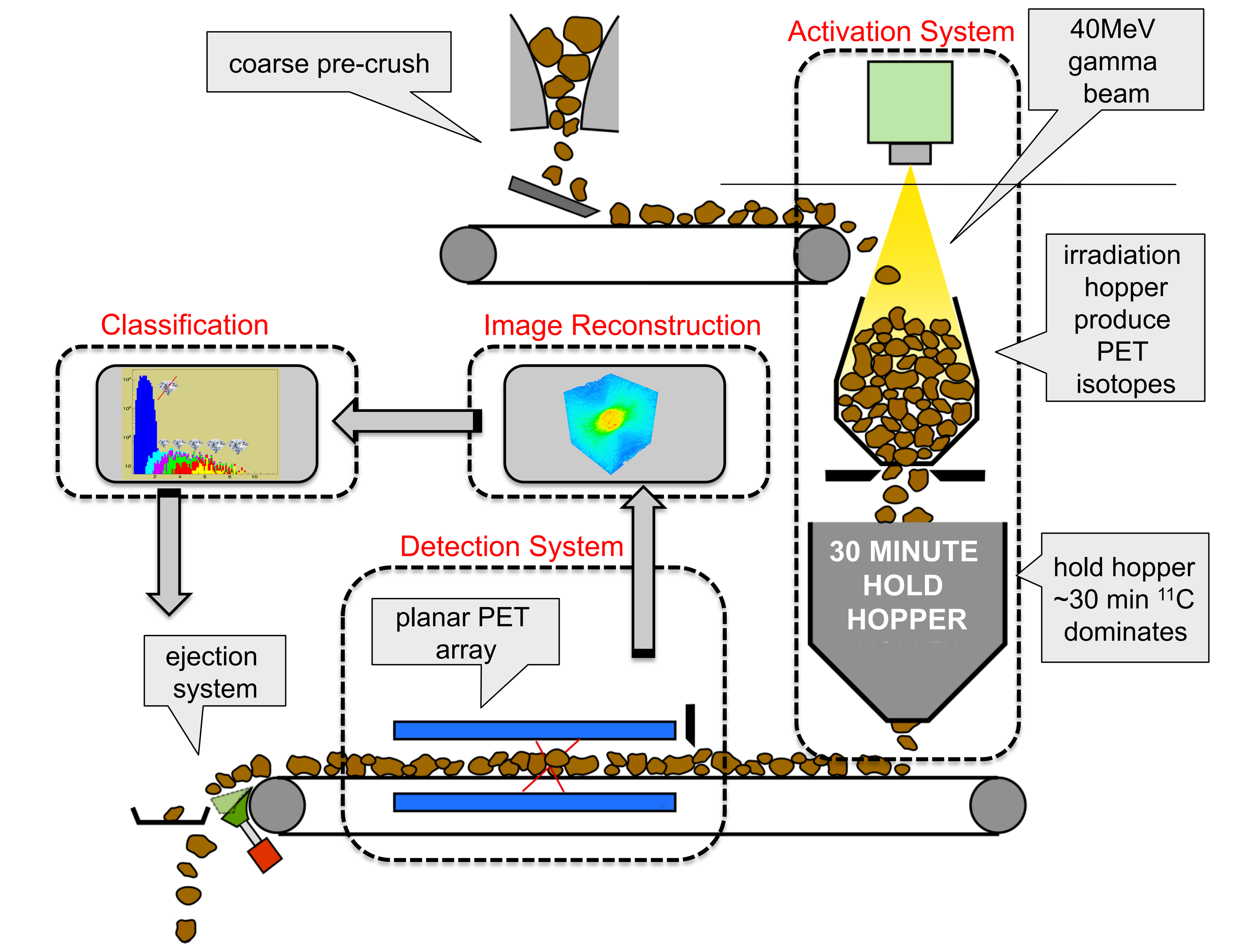


Configuration of XRT sorting machine



Diamonds are rare and an enormous amount of rock must be crushed and processed. Older methods include grease tables as shown above and dense media separation (produces slimes). More novel sensor-based sorting may use Xray Transmission (XRT) as shown above and also X-ray fluorescence. The most modern methods still require significant crushing and are suited to smaller diamonds, liberated or enclosed in kimberlite material that does not dominate the total composition too much. New technology is being studied which is called Mineral Positron Emission Tomography (MinPET). It is capable of detecting 7 mm diameter diamonds within 100 mm diameter rock online in Run-of-Mine conditions [1].

MinPET process



MinPET: sensor-based sorting of diamondiferous from barren kimberlite – Accelerator based Activation of PET isotopes, 3D detection of PET isotope distributions, processing Big Data at High Rates, AI & ML Classification

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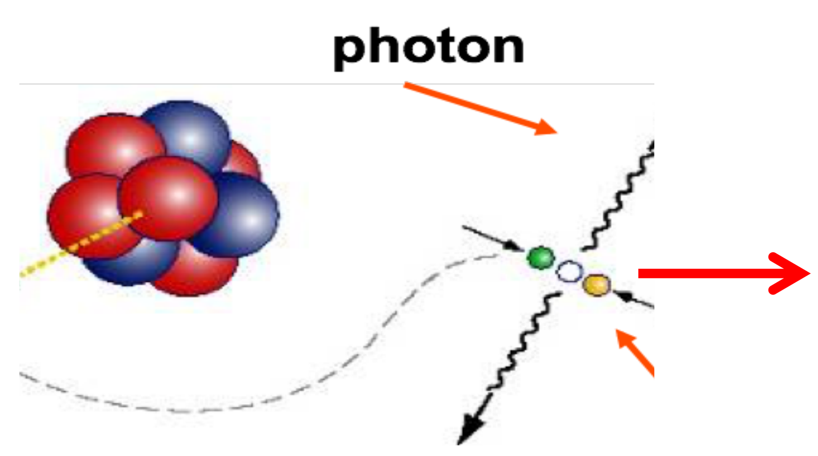
Aarhus Experiment

The Aarhus microtron injector was used to study the activation stage of the MinPET process. It has an electron beam energy of 100 MeV, which we degrade to 40 MeV and then produces bremsstrahlung photons suitable for the (γ,n) production of ^{11}C at the Giant Dipole Resonance. As the kimberlite has a complex composition, many nuclides are produced, and there is a range of reactions that can occur. Gamma spectroscopy after activation is used in a time differential fashion, so both energy and lifetime of the peaks can be extracted.

	Grey Kimberlite	Altered Grey Kimberlite	Black Kimberlite
SiO_2	43.5	39.1	40.96
TiO_2	0.74	0.83	2.21
Al_2O_3	3.66	3.77	2.87
Fe_2O_3	4.90	4.05	5.03
FeO	2.70	2.89	4.28
MnO	0.16	0.25	0.10
MgO	27.85	36.0	27.25
CaO	3.64	0.42	6.02
Na_2O	0.20	<0.1	0.71
K_2O	0.67	0.20	1.22
H_2O+	8.20	9.89	7.47
H_2O-	0.91	1.89	1.10
P_2O_5	0.15	0.13	0.19
CO_2	**0.20**	**0.22**	**0.15**
Total	**97.5**	**99.4**	**99.6**
Ni	1354	950	1338
Cr	728	752	1370
Sr	139	79	n.d.

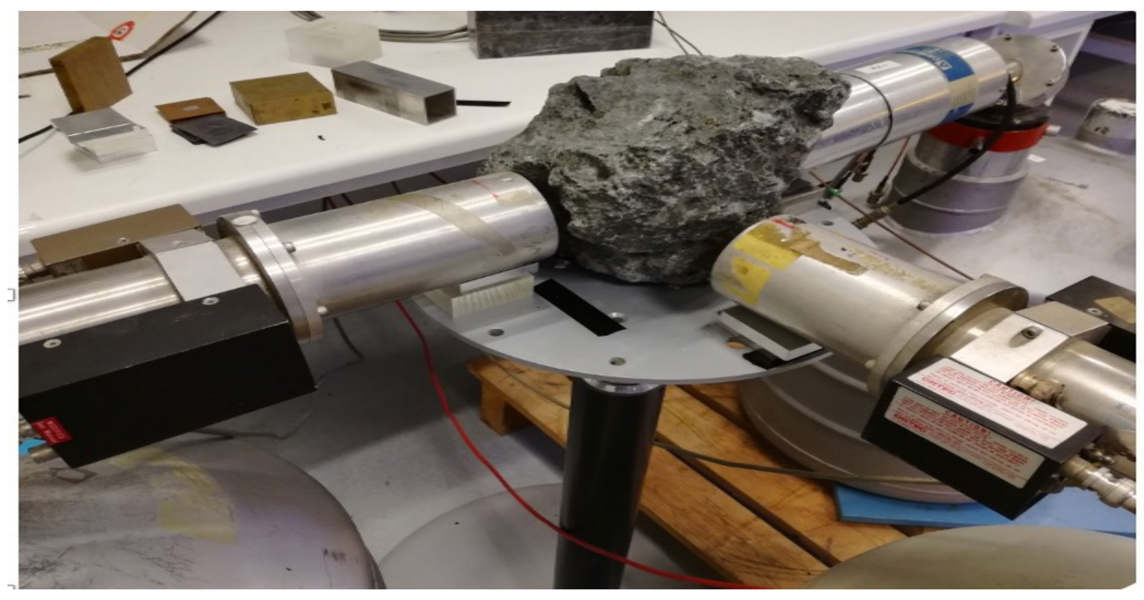
Production of 11C as a PET isotope



$^{12}C(\gamma,n)^{11}C$ reaction

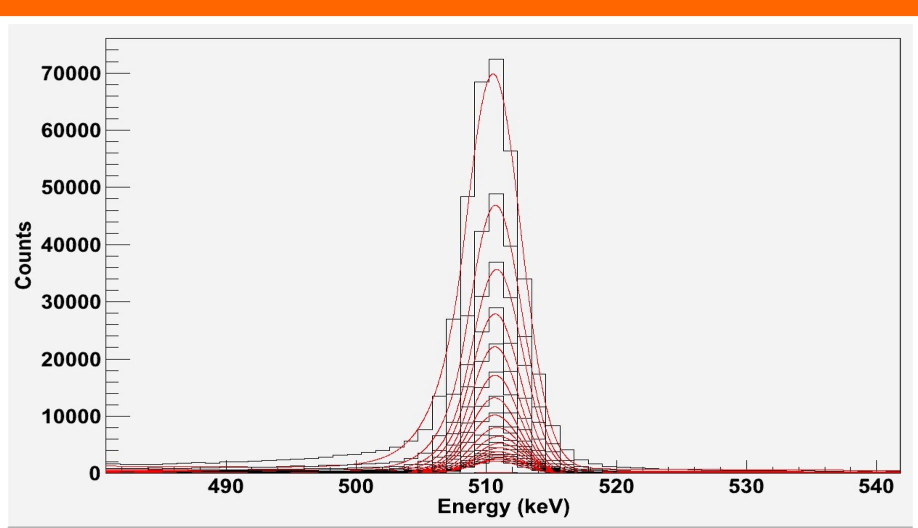
$^{11}C \rightarrow {}^{11}B + e^{+} + \nu^{+} + 0.96MeV$

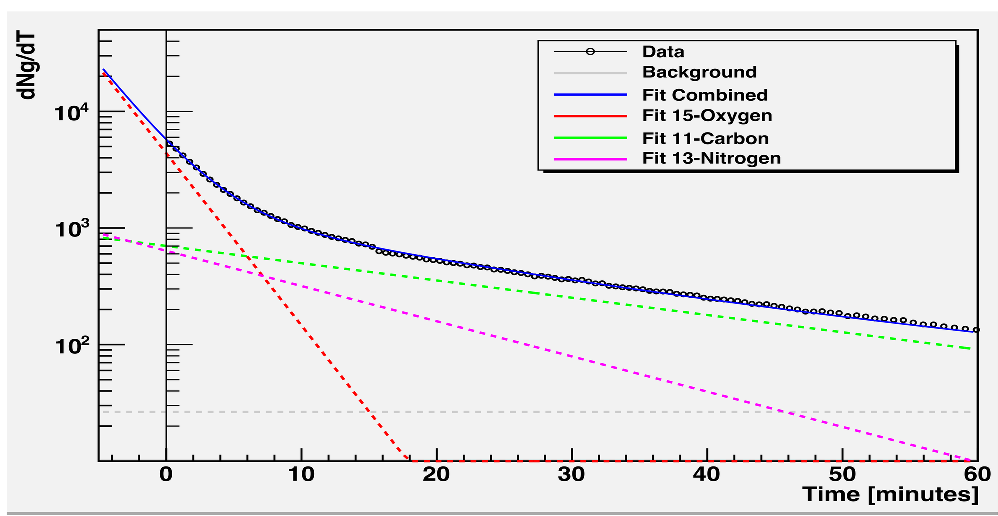
Detection



The kimberlite is placed in between the three High Purity Germanium Detectors for time differential detection after irradiation for 10 minutes and also a cool down period.

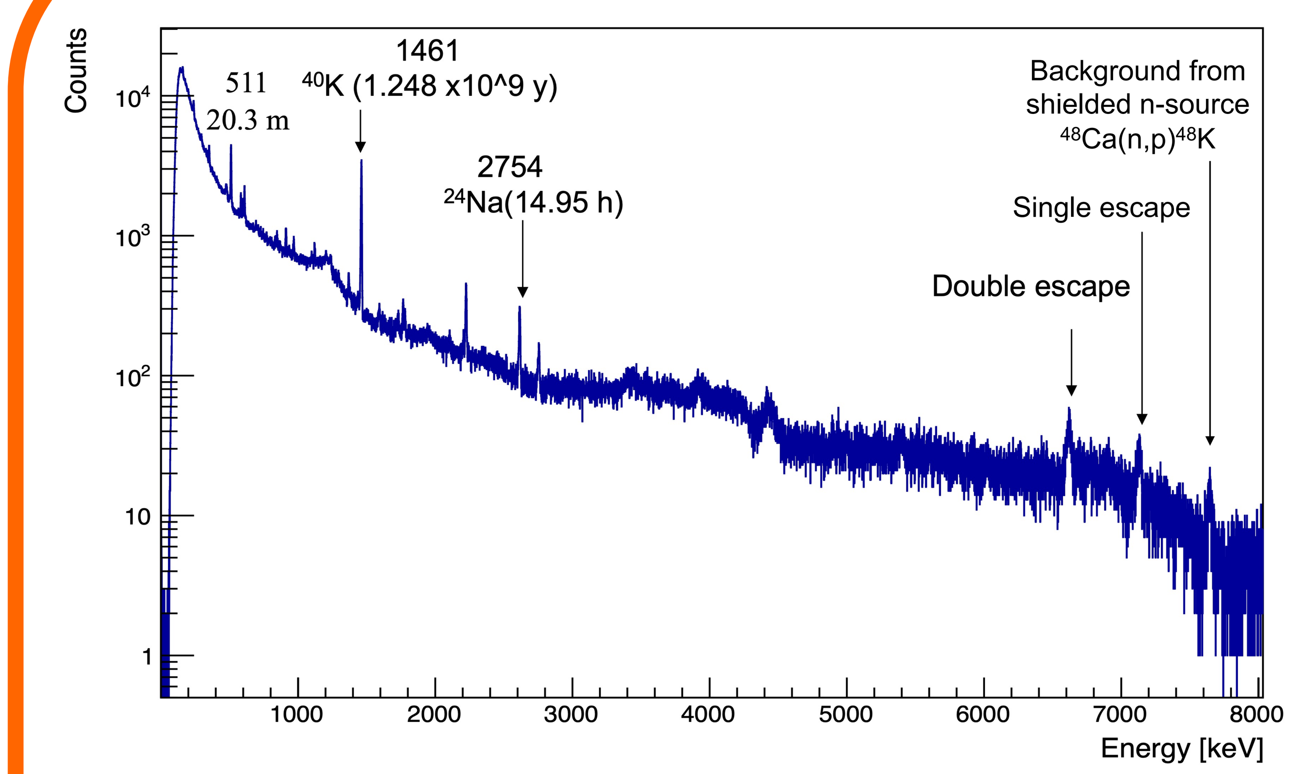
Peak Analysis and time stamp





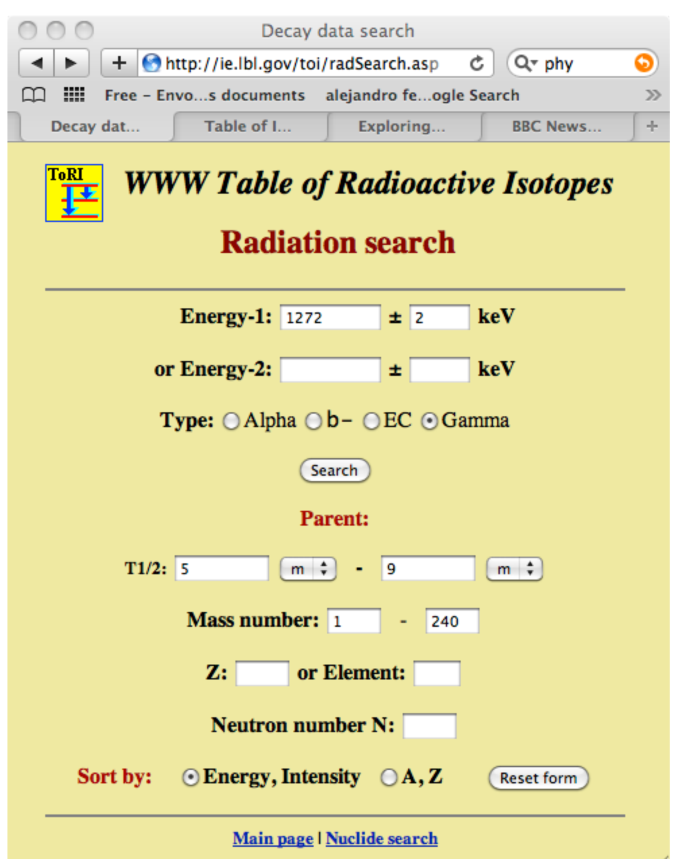
The 511 keV peak E-spectra has been binned at different time slices, then analyzed for different lifetime components.

Results and Conclusions



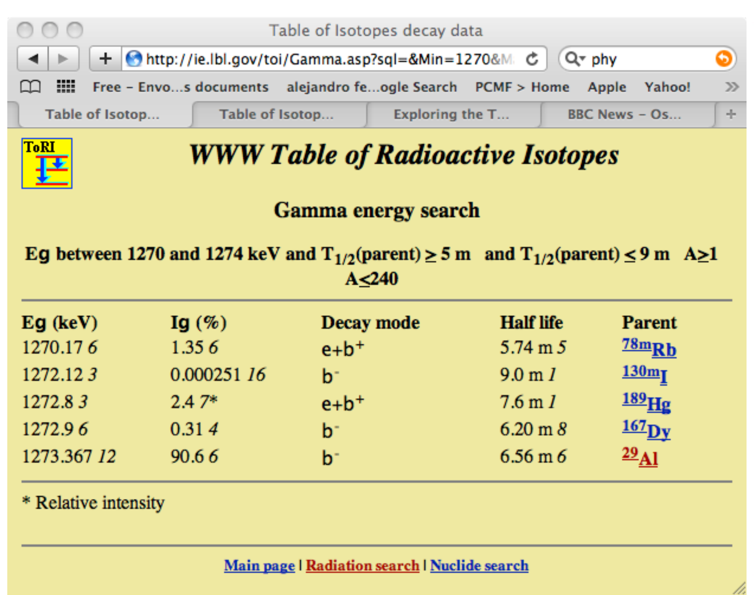
1. Time differential gamma spectroscopy was performed on kimberlite rocks irradiated with high energy photons as in the MinPET activation stage. The irradiation leads to the production of several nuclides via various photon induced reaction pathways.
2. The ID of these nuclides is determined from both energy and lifetime information.
3. Pathway analysis could identify parent elements that lead to these nuclides as identified. In some cases, the pathway analysis was performed using the FISPACT software, which modelled the exposure of the kimberlite elements to the mixed field irradiation process and then decayed the resulting nuclides to match the measurement times. Some examples are shown.
4. Finally, at longer times, natural ^{40}K remains the largest peak in the system, confirming the MinPET method tailings do not require regulation.

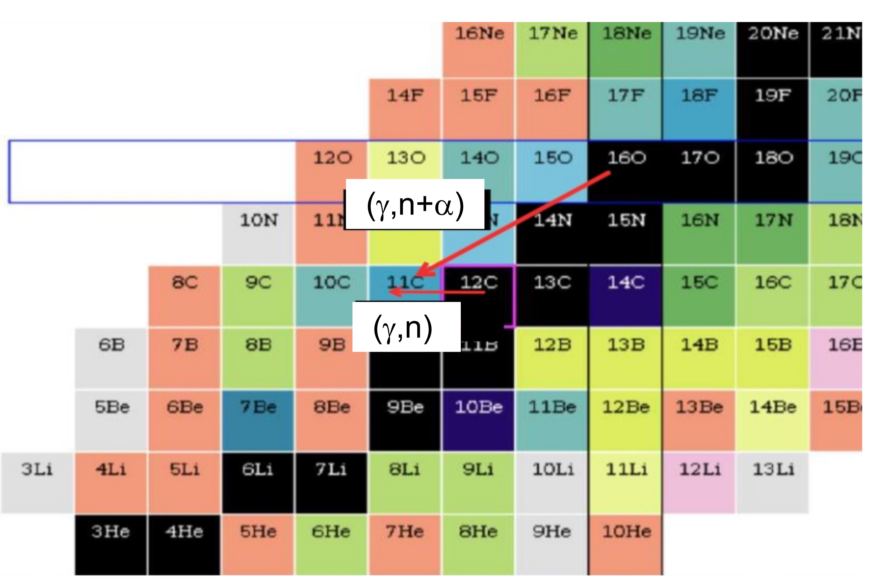
Peak Identification



1273 keV with τ~(5,9) min → ^{29}Al

Pathway Analysis





Parent	Daughter	Reaction	MinPET Activity [Bq/cm^3]
^{12}C	^{11}C	γ,n	957
^{40}Ca	^{38}K	γ,n+p	336
^{54}Fe	^{53}Fe	γ,n	308
^{16}O	^{15}O	γ,n	181
^{16}O	^{11}C	γ,n+α	138
^{46}Ti	^{45}Ti	γ,n	29
		Total kimberlite:	1948
		Diamond activity:	88095

Reactions that lead to significant background as PET isotopes at 23 m after irradiation

[1] T Nemakhavhani et al, The MinPET diamond discovery technique, Proc. SAIP2017, 355-360