BISMUTH GERMANATE GAMMA RAY SPECTRA FROM A CLASSICAL THICK TARGET EXPERIMENT.
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Introduction: Thick target simulation experiments with high energy charged particles were considered to be useful in support of planetary gamma ray spectrometry. Results of a classical Thick Target Experiment using a High Purity Germanium (HPGe) gamma-ray spectrometer at the SATURNE accelerator were summarized recently [1]. A side experiment was conducted at that time measuring gamma rays from the same target with a Bismuth Germanate (BGO) spectrometer. A comparison between HPGe and BGO simulated gamma ray spectra seemed to be of interest, considering successful planetary gamma ray experiments with both detector types [2, 3, 4, 5, 6]. The goal was to investigate backgrounds by comparison of HPGe and BGO gamma ray spectra obtained from the same thick target source. The investigation is in progress. We present here a first identification and analysis of peak areas for the region of each BGO spectra peak.

Methods: Initial work included the extraction of BGO spectra from the data source provided and reformatting and iterative calibration for further use. Qualitative analysis of the spectra was done primarily with the program GANY version for NaI detectors [1, 7]. This provided for a peak centroid determination, and approximate peak area above background estimation with sufficient accuracy for further processing. The recovered and calibrated translated spreadsheet formats for use in in other data reduction and graphics programs. A first approach of comparing BGO and HPGe spectra was the assignment of identifiable spectral BGO structures (peaks) to potential major single energy gamma ray line contributors. Peak area coverage/range consisted of determining the minimum and maximum energy for each peak in the BGO spectra, and comparing it to the equivalent energy region in the HPGe spectra. This included adjustments required for HPGe peaks that sat on one of the borders of the BGO peak and did not contribute significantly to the general shape of the peak. These peaks were still considered in the peak area analysis and comparison to ensure a clearer understanding of all contributions caused by gamma ray lines to a BGO peak.

Results: Analysis of the BGO spectra revealed eight identifiable (peak) structures/features following the 511KeV annihilation peak. The eight identified BGO peak structures are associated with or dominated by the following gamma ray lines: 846KeV Fe, 1274KeV Na, 1779KeV Si, 2223KeV H, 3539KeV Si, 6126KeV O, 7134KeV Fe Single Escape, and 7645KeV Fe. An eye-fit of the spectra while compared with the HPGe spectra suggests a ninth peak structure, located at 3.9MeV which may be composed predominantly of a Silicon double escape line accompanied by a weak Oxygen line at 3.8MeV. The HPGe spectra revealed interactions from gamma rays from Germanium, which were not independently identified in the BGO spectra. The resolution of the BGO made it unreasonable to attempt and resolve individual background lines from the spectra. The next focus was comparing the peak areas identified through GANY of the HPGe spectra and of the BGO spectra to achieve a general understanding of relative contributions of gamma rays to BGO peak structures, assuming comparable peak registration efficiencies over the energy rages under consideration. With this comparison, it was possible to see that roughly twenty percent of the peak area contributing toward the 846KeV Fe peak was caused by Germanium, and only roughly forty percent of the peak area was caused by interactions from Fe.

With the exception of the 511KeV peak, the peaks from 0-2MeV experience contributions from other elements with peak areas totaling approximately fifty-eight percent of the total region. The 511KeV line experienced a fourteen percent contribution from Ge and Na. The 2223KeV H line was found to be eighty percent contribution from H, with the remaining twenty percent from Na, Al, and two small unidentified peaks at 2093KeV and 2166KeV.

The energy region from 4-8MeV is less stable in its contribution rate. The Si BGO peak is forty-seven percent from Si, and the O peak is only thirty-five percent O. However, the Fe Single Escape line is sixty-eight percent Fe and the Fe parent line is nearly ninety-three percent Fe. The average peak area between these four peaks as caused by the peak element identified is roughly sixty-one percent.

This analysis provides confidence that applying the most advanced BGO data deconvolution methods, developed by Prettyman et al. [8], can be applied to the BGO simulation spectra to obtain useful results.

Conclusion: A general background reduction from identification of gamma ray lines caused by interactions with the detector is not feasible at this time. BGO resolution makes identification of these weaker peaks unidentifiable on their own within the

BGO spectra, although their contribution can be somewhat significant to peaks from in the lower energy range. Instead, analysis of BGO peak contribution should focus on the peak areas of elements in the given region. By comparing HPGe spectra of the same target to the BGO spectra, one will be able to identify the amount of expected contribution that should be seen within each BGO peak. Further experiments mimicking that of the Thick Target experiment should be carried out to verify the assumptions made about peak areas, and to identify expected contributions. It is expected that the general results for a mixed target as the basalt target used in the Thick Target experiment will yield similar results with respect to contribution of peak areas.

References[1] J. Brückner J. et al. (2011) Nuclear Instruments and Methods in Physics Research B 269, 2630-2640 [2] Feldman W.C. et al. (1999) Nuclear Instruments and Methods in Physics Research A 422, 562-566 [3] Hasebe N. et al. (2008) Earth Planets Space 60, 299-312 [4] Boynton W.V. et al. (2007) JGR 112, E12S99, doi:10.1029/2007JE002887 [5] Prettyman T.H. et al. (2003) IEEE Transactions on Nuclear Science 50:1190-1197 [6] Prettyman T.H. et al. (2012) Science 10.1126 /science.1225354 [7] Kruse H. (1977) in: Carpenter S. et al. (eds.) Computers in Activation Analysis and Gamma-Ray Spectroscopy, 76 [8] Prettyman T.H. et al. (2006) JGR 111, E12007, doi:10.1029/2005 JE002656

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Explanation of Figures:
Figure 1 shows the HPGe and BGO spectra with peaks identified for the basalt target with proton beam at 1.5GeV. Figure 2 shows the results of the peak area analysis giving only the percentage for the element's contribution, and not showing the full contribution list for each peak.

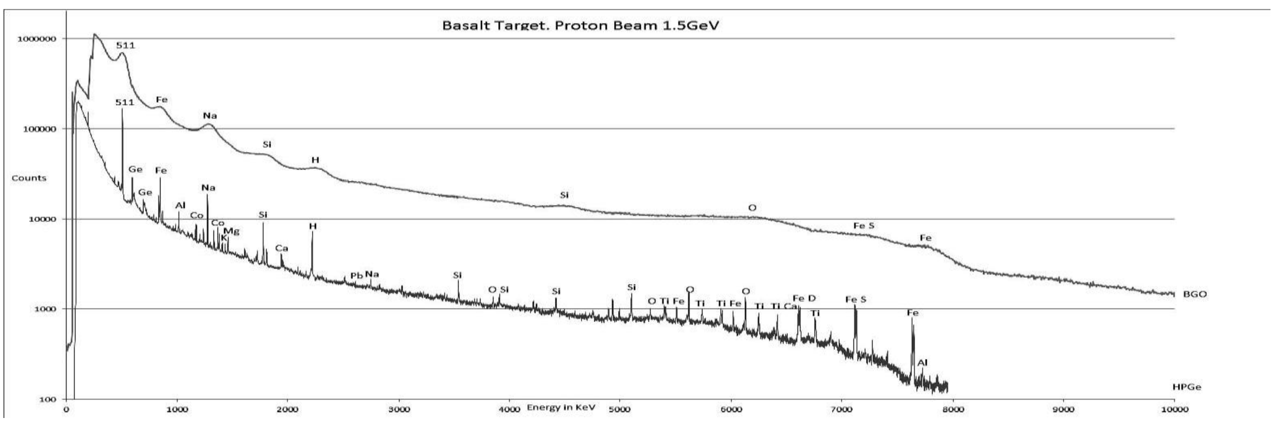

Figure 1. Basalt Target BGO and HPGe spectra, peaks labeled.

ID Peak Element	ID Peak Energy	Peak Area HPGe	Peak Area BGO	# of HPGe Peaks	# of Elements	BGO E Range	% PA HPGe of Total for Region
Annih	511.1	600702	6501904	8	5	390-580	86.87
Fe	846.7	55745	718809	16	9	750-1100	39.75
Na	1274.5	46602	1072521	14	9	1100-1435	37.99
Si	1779	25946	293737	7	6	1500-1900	51.16
H	2223.2	22680	439056	4	3	2000-2450	80.25
Si	4422.9	2758	76439	3	3	4050-4650	47.66
O	6128.6	5260	134342	15	4	5020-6650	35.25
Fe S	7133.3	6106	97258	6	3	6650-7525	67.99
Fe	7645.5	3866	33407	4	3	7525-8100	92.44

Figure 2. Peak area analysis for BGO and HPGe spectra of basalt target with proton beam at 1.5GeV