Contribution of Heavy Elements to the Milagro Background Rate

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Introduction:
In this memo I examine the contribution of heavy elements (Z>2) to the Milagro trigger rate. I find that the combined contribution of heavy elements is non-negligible and can probably account for the deficit observed in prior trigger rate estimations. In this work however, I don't attempt to compute the trigger rate, but rather I compute the relative contribution of heavy elements. A detailed trigger rate study is underway. This work was greatly aided by the recent publication of heavy element spectra by the ATIC experiment [1,2].

BOTE Computation:
As a starting point, we can do a simple back of the envelope (BOTE) computation of the contribution of heavy elements. Figure 1 shows the spectrum for all particles with Z>3 and the adjacent figure shows the spectrum for protons. Both spectra are approximately flat on this plot indicating that they have a spectral index of ~-2.75. At 1-10 TeV, the flux of both protons and trans-Boronic heavy elements is approximately the same, ~1-2 x 10^4 in these units. So, at first look, I would conclude that the contribution from heavy elements is approximately equal to that of protons. Wow! This is in fact not quite true as the effective area for heavy elements is not the same. A 1 TeV proton interacts like a single particle whereas a 1 TeV iron nucleus interacts like a collection of 56 loosely bound independent nucleons, each carrying only a small fraction of the energy. As a result, the "threshold" for heavy elements is much higher than for light ones at the same energy and a detailed simulation is required. However, at high energies (>10s of TeV), where the effective area is large and flat for all hadrons, heavy elements will contribute to the background at the same level as protons. Wow again! And to think, we don't simulate them.

Detailed Computation:
The relative contribution of each heavy element depends on a number of factors: charge, elemental abundance etc. It is not clear to me how one would derive the contribution from each element from first principles, so it is very important that the nice people at ATIC have made the measurement for us. In their paper, they measure the specra of 6 easily distinguishable elements: C,O,Ne,Mg,Si and Fe. They can also measure the relative abundance of B,N,F,Na,Al,P and S compared to the 6 well measured elements. They don't actually publish spectral fits, but I read the numbers I needed off their plots with sufficient precision.

Using our standard Corsika and GEANT code, I simulated the 6 well measured heavy elements. I then pass them through the same analysis chain that I use for the estimation of trigger rates using protons and helium. To remove the effects of trigger thresholds, I consider only events with >=85 AS layer hits. The results are listed in table 1 below. I then estimate the contribution of the poorly measured elements from figure 3 below from the ATIC paper. I estimate the combined contribution from Cl-Mn (9 elements before Fe) from another figure in the ATIC paper to be 0.5 times the contribution of Fe.

I find that the total contribution of heavy element is ~160 Hz or approximately 37% of the proton only rate and neatly equal to the contribution of Helium. This is probably enough addition triggers to bring the predicted Milagro trigger rate within agreement with the measured rate. We have also found in the past that the trigger rate deficit is larger with increasing threshold, which is consistent with this result as the contribution of heavies grows with energy.

Conclusions:
We need to simulate heavy element to make thing work right. We particularly need them at high energies. There may be topological differences between heavy and light elements that effect gamma-hadron separation, but this has yet to be explored. I am working on making it easier to simulate backgrounds by combining all the elements.

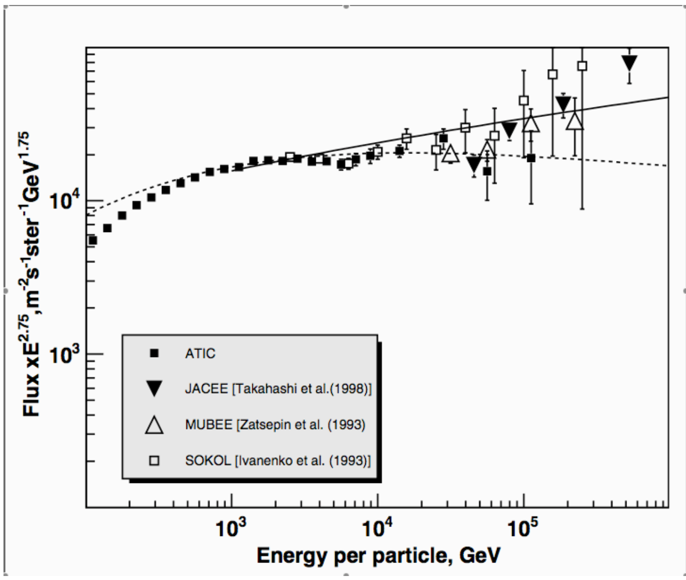

Figure 1. Heavy nucleon spectrum from ATIC.

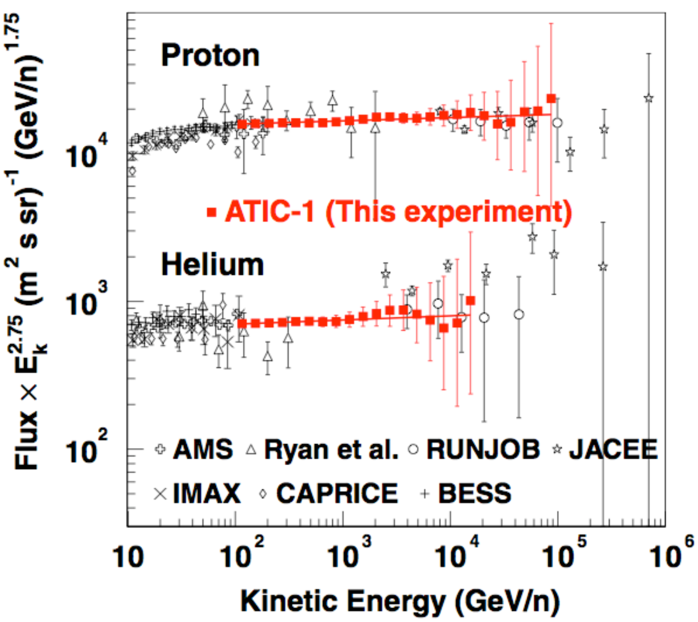

Figure 2. Proton and Helium spectra from ATIC.

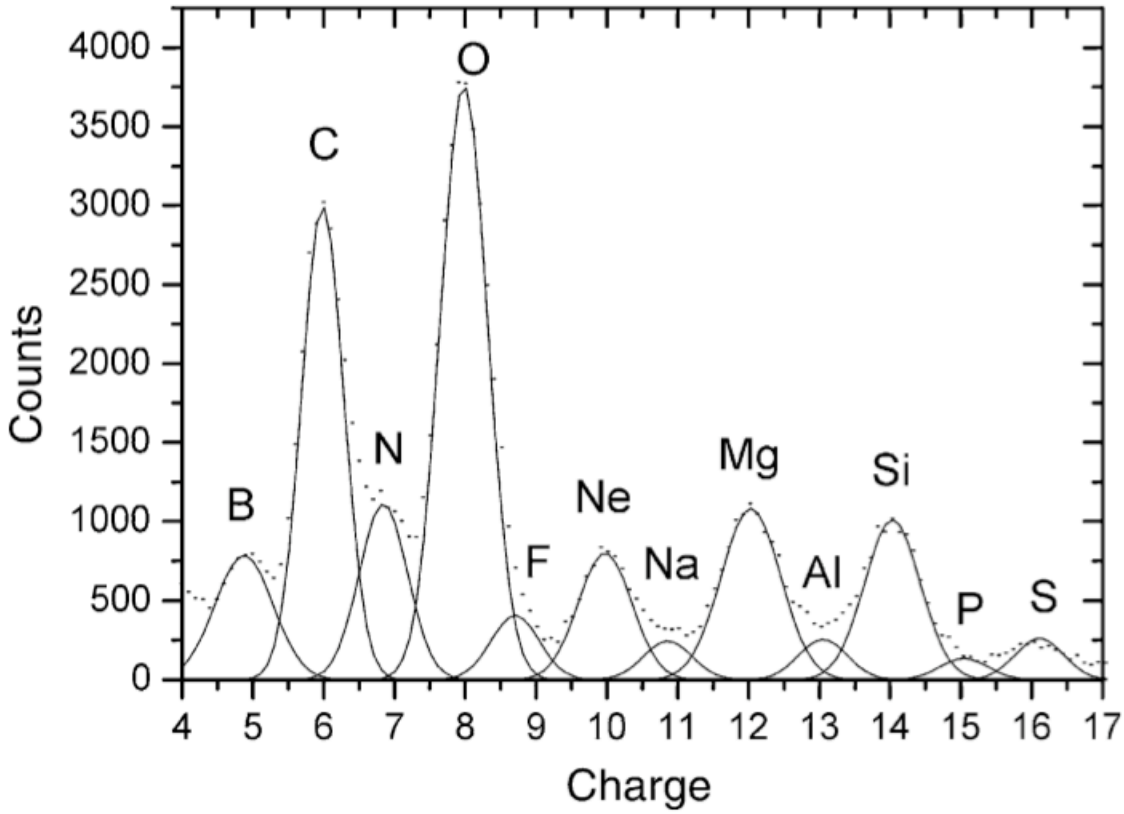

Figure 3. Heavy nucleon abundance from ATIC.

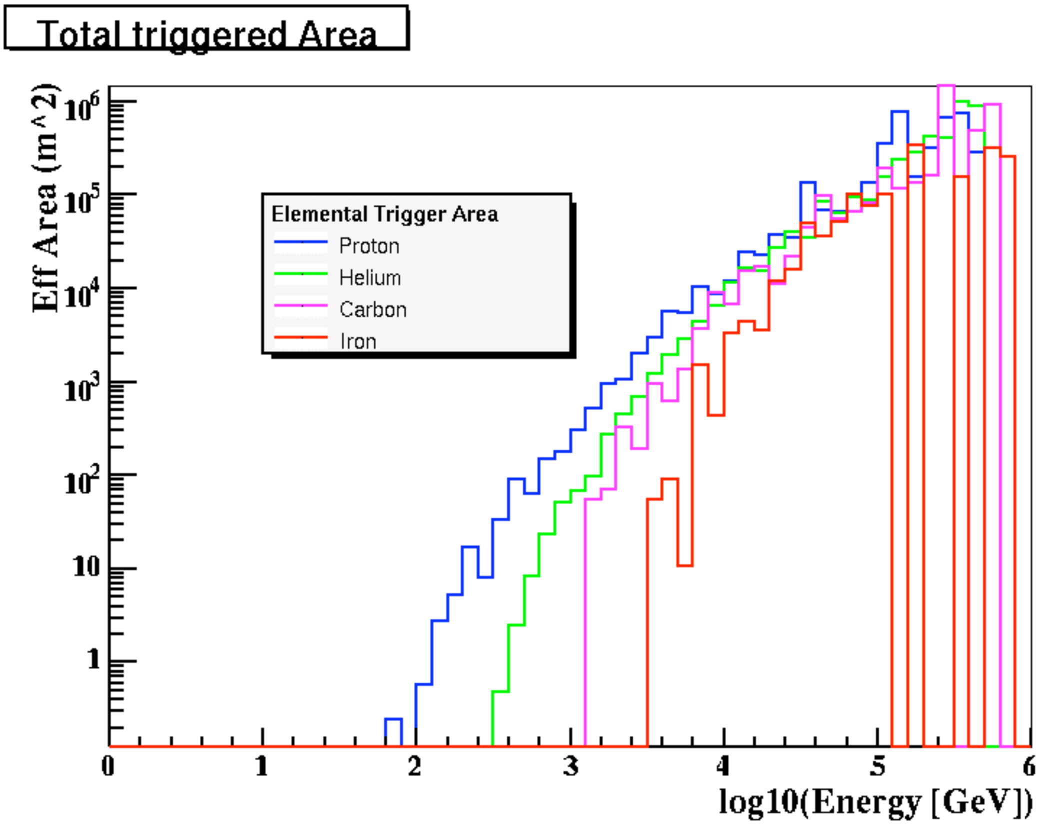

Figure 4. Total triggered area for Milagro.

Table 1. Contribution to rate by element.

Z	Element	Rate (Hz)	Comments
1	H	431	Good ol protons
2	He	159	He matters. We always knew that
3,4	Li,Be	---	These guys don't matter. Ask a nuclear physicist why
5	B	3.2	Estimated from relative abundance compared to C
6	C	16.0	From ATIC spectrum
7	N	8.0	Estimated from relative abundance compared to O
8	O	26.6	From ATIC spectrum
9	F	2.7	Estimated from relative abundance compared to O
10	Ne	8.6	From ATIC spectrum
11	Na	2.8	Estimated from relative abundance compared to Ne
12	Mg	10.3	From ATIC spectrum
13	Al	2.6	Estimated from relative abundance compared to Mg
14	Si	15.7	From ATIC spectrum
15	P	1.9	Estimated from relative abundance compared to Si
16	S	3.9	Estimated from relative abundance compared to Si
17-25	Cl-Ar	19.5	Estimated from relative abundance compared to Fe
26	Fe	38.9	From ATIC spectrum
	Total	750.0	

1 Advances in Space Research 37 (2006) 1944–1949

2 Advances in Space Research 37 (2006) 1950–1954