A Data-Driven approach for the measurement of ^{10}Be/^{9}Be flux ratio in Cosmic Rays with magnetic spectrometers

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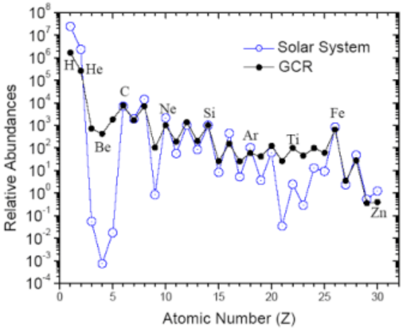
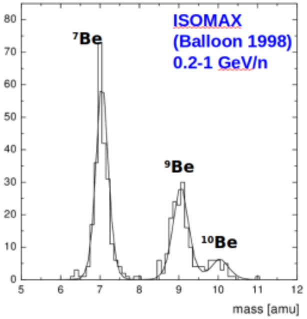
The ^{10}Be/^{9}Be flux ratio (thanks to the 2 My lifetime of ^{10}Be) is a radioactive clock providing the measurement of CR residence time in the Galaxy. Existing measurements of ^{10}Be/^{9}Be in CR are limited to low energy and affected by large uncertainties, in particular from the Montecarlo simulation. A Data-Driven approach in magnetic spectrometers is presented, as an example it is applied to PAMELA data providing a new measurement in the 0.25-0.85 GeV/n range.

Isotopes of Beryllium in cosmic rays





Be isotopes in CR:

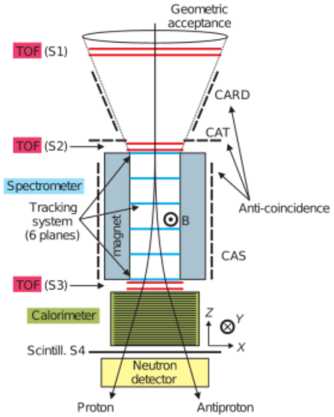
^{7}Be (E.C. $T_{1/2}$=55d)
("naked" ^{7}Be is stable)

^{9}Be (stable)

^{10}Be (β $T_{1/2}$=1.39My)
(is a radioactive clock)

Be is scarce in CR not produced by stellar nuclesynthesis
Be is a secondary CR prduced by CNO spallation with ISM

PAMELA experiment

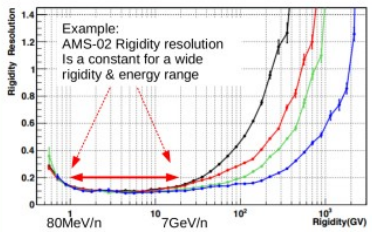


ToF: $\beta = \frac{v}{c}$

TRK: $\frac{RZ}{\beta\gamma} = M$

Calo: $\frac{dE}{dX}(\beta)$

Mass & R resolution



$$\frac{\Delta M}{M} = \sqrt{\left(\frac{\delta R}{R}\right)^2 + \gamma^4 \left(\frac{\delta\beta}{\beta}\right)^2}$$

For a fixed $E_k/n = (\gamma - 1)0.9315$ GeV $\frac{\Delta M}{M}$= const. => mass template scaling

Templates T_7 ,T_9 and T_{10} are the three unkown mass distributions.

The "Data-Driven" approach: recipe summary

The three Be mass are similar, a linear approximation is applied. σ_a is the RMS of T_a and x_a is the median of T_a. The (linear) transformation $L_{a,b}T_a = T_b$ is the function: $x \to \frac{\sigma_a}{\sigma_b}x + \left[x_a - \frac{\sigma_a}{\sigma_b}x_b\right]$.

The same transformation but applied to a different, template $L_{a,b}T_c = T_d$ is:

$\sigma_d = \sigma_c\frac{\sigma_b}{\sigma_a}$ and $x_d = x_b + (x_c - x_a)\frac{\sigma_b}{\sigma_a}$.

The known (measured) data distribution is $D(x)$, thus this system must be solved:

$$D(x) = {}^7BeT_7 + {}^9BeT_9 + {}^{10}BeT_{10}$$
$$L_{7,9}D(x) = {}^7BeT_9 + {}^9BeL_{7,9}T_9 + {}^{10}BeL_{7,9}T_{10}$$
$$L_{7,10}D(x) = {}^7BeT_{10} + {}^9BeL_{7,10}T_9 + {}^{10}BeL_{7,10}T_{10}$$

The ^{7}Be template can be written as:

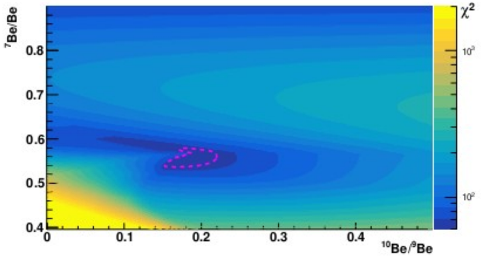
$$T_7 = \frac{1}{^7Be}\left[D - \frac{^9Be}{^7Be}L_{7,9}D - \frac{^{10}Be}{^7Be}L_{7,10}D\right] +$$
$$+\left(\frac{^9Be}{^7Be}\right)^2 T_{G1} + \frac{^9Be}{^7Be}\frac{^{10}Be}{^7Be}(T_{G2} + T_{G3}) + \left(\frac{^{10}Be}{^7Be}\right)^2 T_{G4}$$

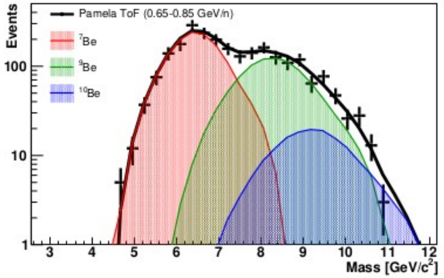
the last four terms, are defined by:

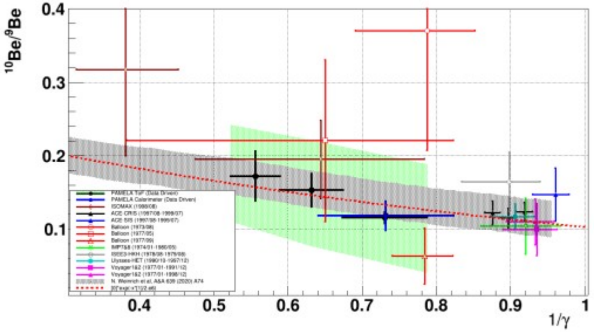
$$T_{G1} = L_{7,9}T_9 = L_{7,x_{G1}}T_7 \quad T_{G2} = L_{7,9}T_{10} = L_{7,x_{G2}}T_7$$
$$T_{G3} = L_{7,10}T_9 = L_{7,x_{G3}}T_7 \quad T_{G4} = L_{7,10}T_{10} = L_{7,x_{G4}}T_7$$

T_7 can be iteratively evaluated for each fixed ^{7}Be > ^{9}Be > ^{10}Be configuration T_9 and T_{10} are obtained by scaling T_7 and a χ^2 is evaluated. Three un-physical $\chi^2 = 0$ solutions are ^{n}Be/Be=1. Use of the statistical bootstrap is suggested for confidence intervals of physical solution.

"Data-Driven" applied to PAMELA Be events: a new ^{10}Be/^{9}Be measurement







Data-Driven approach allows a new measurement in 0.25-0.85 GeV/n.

Green shaded area is a (cautious) systematic error.

First experimental hint for time dilation effect in ^{10}Be/^{9}Be.

Adopting a minimal model: $^{10}\text{Be}/^9\text{Be} = \text{A}e^{-\frac{T}{\gamma\tau}}$ (known τ = 2My)

A = 0.27 ± 0.13 and T = 1.9 ± 1.1 My (dominated by PAMELA data)

Data-Driven approach allows an independent test of Montecarlo systematics. Next step is the measurement using AMS-02 data.