ELECTRON AND POSITRON SPECTRA FROM PAMELA BY MULTIVARIATE DATA ANALYSIS METHODS

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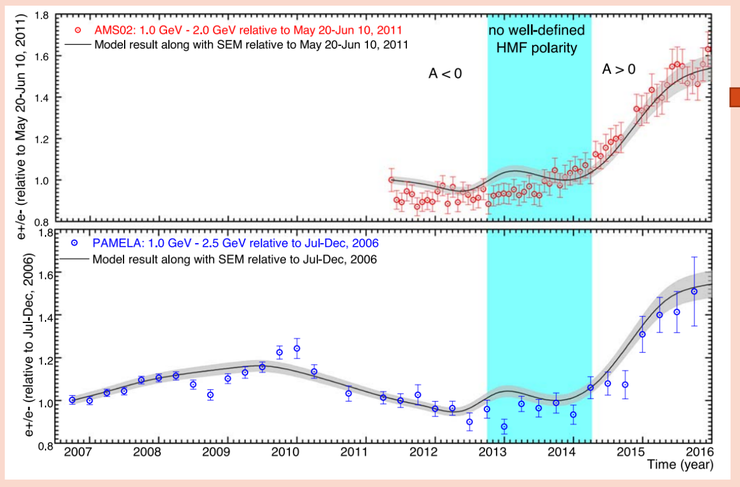
WHY

Positron to electron flux ratio:
Modeling and experimental data



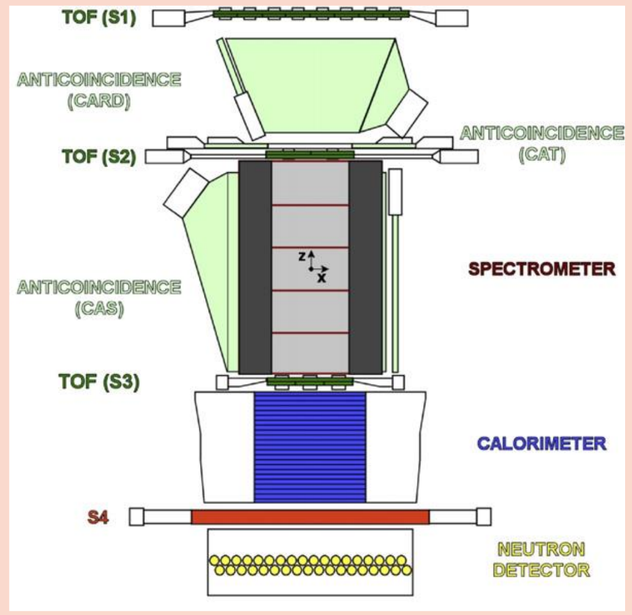
[The Astrophysical Journal, 909:215 (2021)]

Current modeling works for cosmic-ray electron and positron fluxes (e. g. by Potgieter) undergo adjusting to account for experimentally observed features. For this, new experimental data are required with energies below 1 GeV and detailed enough timeline.

PAMELA detected:
e-,e+: 50 MeV – hundreds of GeV
p: 80 MeV – TeVs
nuclei (He, etc.): …

Orbit: alt. 350–600 km; dec: 70°
Dataset: 2006–2016 (~1 solar cycle)
(e-, e+ published* for 2006–2009 only)

PAMELA detector systems



[Astroparticle Physics, 27: 296–315 (2007)]

** [Physical Review Letters, 106(20): 201101 (2011); 111(8): 081102 (2013)]*

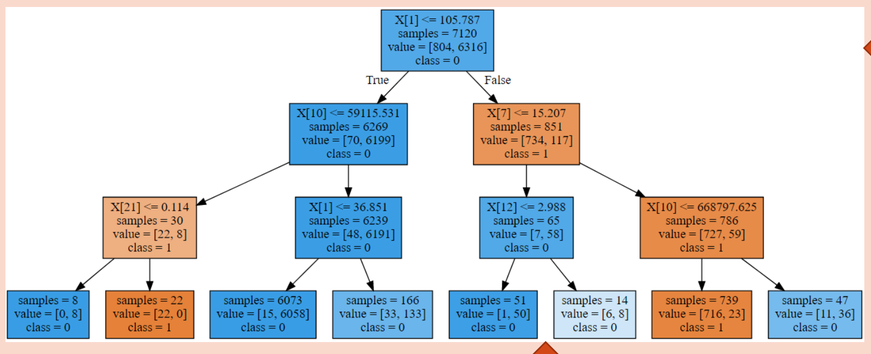
To achieve:

lower energies: down to 50 MeV
smaller time step: ~27 days
complete dataset: for 2006–2016

Main task:
to optimize the selection method
to increase the output statistics

HOW

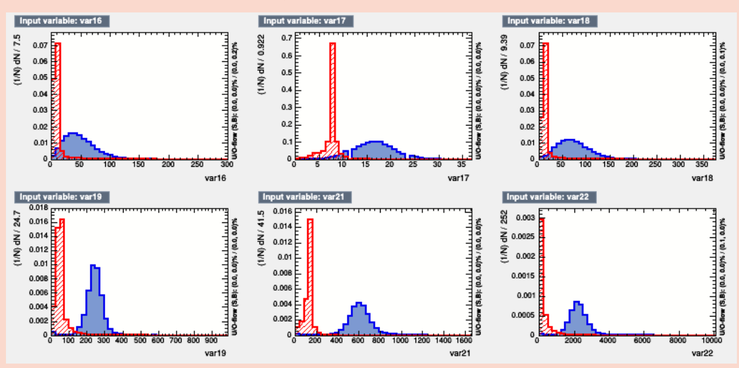
Instead of manual setting selection criteria, machine learning methods were used to analyze > 20 parameters from the PAMELA database (mainly, the calorimeter data).



Method used: Boosted Decision Tree

Training: GEANT4 modeling data for electron and proton events, 0.05–3 GeV
Testing: PAMELA database

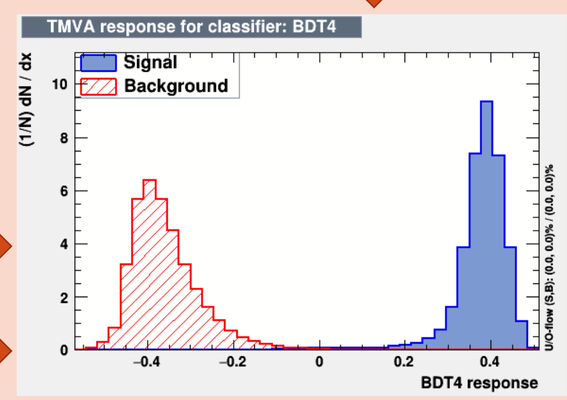
Effective selection: BDT4 > 0.2



Events are divided into 2 classes based on the analysis of their parameters with each priority and weight and the analysis depth set.

These classes are:
Signal: electrons background: protons

The algorithm returns a combined parameter that is more convenient to use.

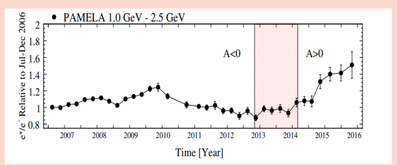


Up to 1.5 times increase of statistics is estimated (compared to the previous manual approach)

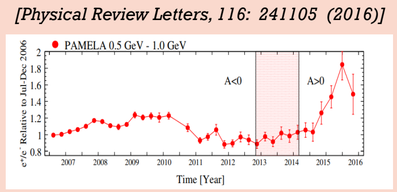
Preliminary results have been obtained to observe charge-sign dependent solar modulation features:

WHAT

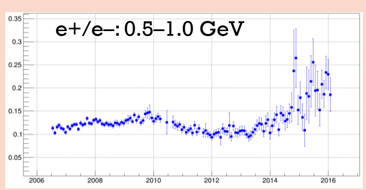
Positron to Electron flux ratio:



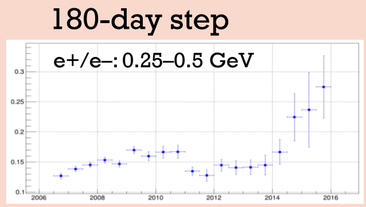
[Physical Review Letters, 116: 241105 (2016)]

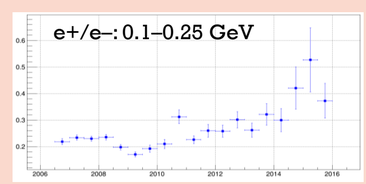


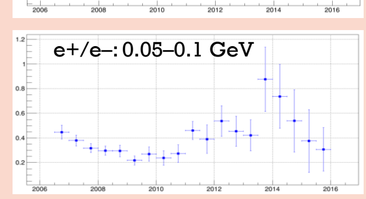
27-day step



180-day step







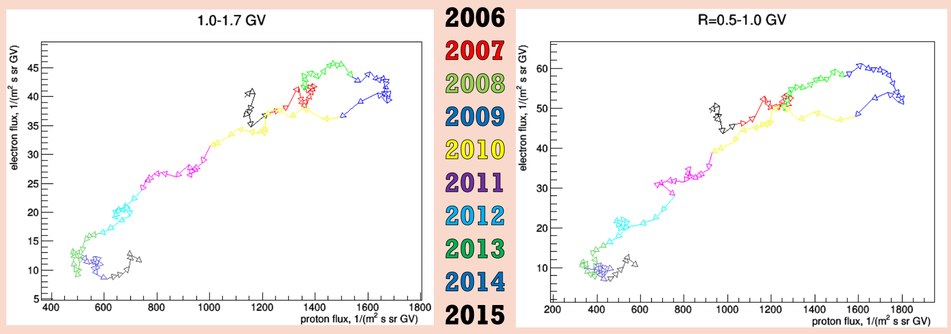
For energies ~ 1 GeV, the results have been obtained with the aimed 27-day time step, consistent with the published ones.
For the lower energies, due to lower statistics, a bigger time step is more presentable.
Still, 2006–2009 show various modulation features, whereas the later years may only suggest a rising trend after the HMF polarity change within statistical errors.

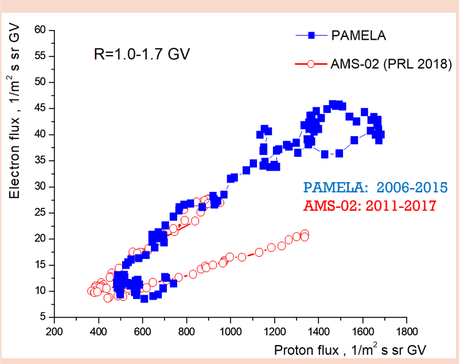
Note:
2008-2009: solar minimum

After 2013: the heliospheric magnetic field (HMF) polarity change

2014-2015: solar maximum

Electron vs Proton fluxes:





Since the results are preliminary, they may change if necessary corrections are applied

Currently, comparing the opposite charge signed fluxes allows observing a "hysteresis" loop around the solar minimum period and other local features from the PAMELA data.

Adding the AMS-02 data shows another regression trend after the HMF polarity change.

Final note: machine learning methods may optimize processing big amounts of data that require strict classification and increase the output statistics if used correctly.