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A multivariate approach to cosmic deuterons and antideuterons analysis with AMS-02

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Summary. — In this work are presented the main features of the analysis methodology developed for the distinction of (anti)deuterons in cosmic rays with the AMS-02 experiment. In particular two different multivariate analysis tools are developed to minimize background contamination in (anti)deuterons sample.

1. – Deuterons in cosmic rays

In cosmic rays (CR) production models deuterons (d) are created from spallation reaction between CR primaries (mostly p, anti-p and He) with nuclei of interstellar medium (p and He). For this reason their abundance in CR can be used to constrain parameters in propagation models for galactic CR [1]. A wide acceptance space experiment such as AMS-02 can perform measurement of deuterium abundance without suffering of contamination from secondary deuterium originated in collisions of CRs in the upper part of the atmosphere.

2. – Antideuterons in cosmic rays

Antideuterons are among the most promising galactic CR-ralated targets for dark matter (DM) indirect detection. Production models [2] show that antideuterons coming from DM annihilation can magnify even of 2 or 3 orders of magnitude the ultra rare antideuterons signal from standard cosmi sources. The discovery of a substantial amount of antideuterons in cosmic rays could be therefore an important indirect evidence for Dark Matter annihilation in space. Thanks to its long expected exposure time (10–20 years), its wide acceptance and its isotopic distinction power, AMS-02 has some potential for this discovery.

3. – The instrument: AMS-02

The Alpha Magnetic Spectrometer (AMS-02) is a magnetic spectrometer installed on International Space Station, whose components include a solid state Tracker for determination of charge signum, charge value and rigidity (momentum/charge), a Time-of-Flight detector (TOF) and a Cherenckov detector (RICH) for particle velocity, and a Transition Radiation Detector (TRD) for adron/lepton discrimination.

4. – Analysis description

The purpose of this work is to show the main features of the analysis strategy that was developed to separate (anti)deuterons from (anti)protons and other sources of background in CR. The analysis strategy has been widely tested on the official Monte Carlo (MC) simulations of AMS collaboration and its application on real AMS data is in progress.

4˙1. *Preselections.* – The preselections are the minimum requirements that an event must fulfil to participate tha analysis. Events with more than 1 recognized track in one of the subdetectors or without a matching of subdetectors signals with tracker track are rejected.

4˙2. *(Anti)deuterons distinction.* – The isotopical distinction in a magnetic spectrometer is usually demanded at the calculation of mass from the value of rigidity (R) and β through the relation $M = \sqrt{\frac{1-\beta^2}{\beta}}$. This distinction is made possible by natural resolution of the two velocity measuring subdetectors in AMS in two ranges. For TOF the limit is $T < 1\,\mathrm{GeV/nucl}$. Using RICH the precision is higher, allowing distinction until $8\,\mathrm{GeV/nucl}$, but efficiency is negligible for $T < 2\,\mathrm{GeV/nucl}$.

4˙3. *Sample cleaning.* – Events that go through interaction within AMS can lead to mismeasured velocity and therefore particle misidentification. This can lead to important p background in d sample. To reject these events two multivariate strategies were tested:

BDT-based:. – Based on the search of traces of multiple interactions or scattering using Boosted Decision Trees (BDT) discriminant trained on MC of d and p using variables sensitive to interactions. These variables includes the number of clusters in excess in TOF or Tracker and the difference between rigidities measure with upper-lower part of tracker.

β consistency check:. – The consistency of measured β with the energy deposition in TOF, Tracker and TRD is checked using maximum likelihood technique. This was implemented calculating the minimum distance in the 3-dimensional space of the parameters (β, R, En.depos.) of the measured values from the theoretical expected ones. Events with high distance are rejected.

5. – Conclusions

Limits of the AMS-02 experiment in the (anti)deuterium isotopical distinction have been investigated using particular MC simulations. Two independent multivariate methods have been developed and cross-checked to maximize purity in (anti)deuteron sample.

REFERENCES

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