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POSITRON/PROTON SEPARATION USING THE AMS-02 TRD

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ABSTRACT

AMS-02 is a cosmic ray experiment that will be placed on the International Space Station. One of its goals is to search for WIMP Dark Matter, specifically from anomalous features in the positron spectrum. In order to identify positrons at high energy from the large background of protons, a Transition Radiation Detector (TRD) will be used. Here we will present studies of positron/proton separation using the TRD from the AMS-02 Simulation.

1 DARK MATTER SEARCH

One of the leading candidates for dark matter is WIMPs (Weakly Interacting Massive Particles) of which a favored type is the supersymmetric (SUSY) neutralino, a linear superposition of the SUSY partners to the photon, Z^0, and Higgs bosons. There is a finite cross-section for neutralinos to annihilate with each other and thus produce standard particles such as positrons, electrons, anti-protons, etc. The output of such annhilations in the Milky Way halo may be detectable as a bump in the power-law spectrum of positrons [1].

2 AMS TRD Simulation

Transition radiation occurs when a highly relativistic ($\gamma > 300$) charged particle passes through a material with varying index of refraction and emits an X-ray. A simulation code primarily based on Geant 3.21 is used to study the ability of the TRD to separate highly relativistic positrons from slower protons with the same energy [2]. The TRD geometry includes 20 layers of radiator and straw tubes with a mixture of gaseous Xe:CO_2 in a ratio of 80:20 by volume. The code simulates TR photon generation/absorption as well as standard $\frac{dE}{dX}$ loss in the thin Xe gas layers of the straw tubes and has been shown to reproduce test beam results.[3]

3 Positron/Proton Separation Algorithm

These studies used monoenergetic (50 GeV) protons/positrons generated at random angles and positions above the AMS detector. A log likelihood method was used to separate the positrons from the protons.[4] The log likelihood is defined as:

$$\mathcal{L} = \sum_{i=1}^{N} log \frac{P\left(dE_i|e\right)}{P\left(dE_i|p\right) + P\left(dE_i|e\right)} \tag{1}$$

where N is the number of straw tube hits in a particular event. $P\left(dE_i|e\right)$ and $P\left(dE_i|p\right)$ are probability density functions for a positron (e) and proton (p) to deposit energy dE_i in the ith straw tube, respectively. The current method of evaluating e/p separation starts with creating distributions of energy deposited in each straw tube for protons and positrons using the AMS simulation. One hit is the total energy deposited in a particular straw tube for an event, and may include $\frac{dE}{dX}$ and TR X-rays. Normalizing these histograms by the total number of proton (positron) hits we get the probabilities that a proton (positron) will deposit a specific amount of energy in a straw tube. Next we use the log likelihood ratio estimator in Equation 1 to create distributions of $\mathcal{L}$, for both positron and proton events.

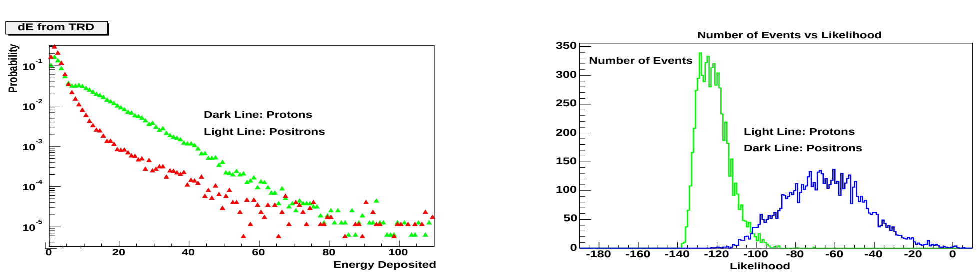

Figure 1: *Probability of Energy Deposited and Likelihood Ratio Estimator*

Then the fraction of positrons (protons) above a threshold likelihood $\mathcal{L}_{th}$ defines the positron efficiency (proton contamination). Integrating to the right of $\mathcal{L}_{th}$ determines the efficiency vs $\mathcal{L}_{th}$. Our goal is to minimize the proton contamination while keeping a reasonable positron efficiency. Finally we plot proton contamination vs positron efficiency, where each point of the plot corresponds to a different $\mathcal{L}_{th}$. To compare particle separation qualities for different configurations, we choose a threshold likelihood for which 90% of the positrons satisfy the likelihood cut.

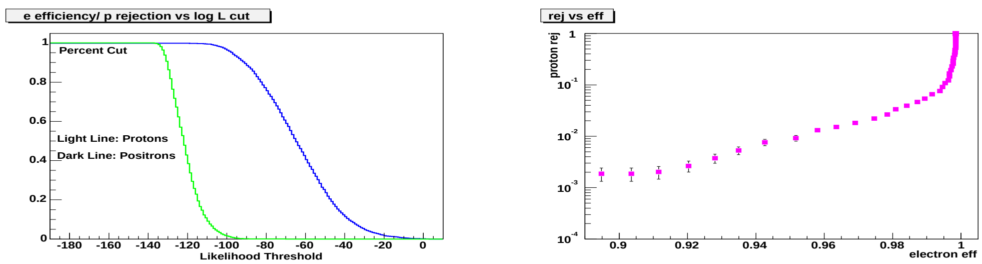

Figure 2: *Integrated Efficiency and Proton Contamination vs Positron Efficiency*

4 STUDIES AND RESULTS

Initial results showed that proton rejections of approximately 10^{-3} could be achieved while only throwing away 10% of the positron signal. This was obtained by using all the hits in each event. Studies were conducted at different particle momentum. The results agreed with the expectation that the separation became worse as the momentum rose and protons themselves began to emit transition radiation. Removing even 2 layers had a drastically negative affect on the separation (factor of 1.5 at 100 GeV). Studies were also conducted to determine how noise in the gas-gain would affect the positron/proton separation. Uncorrelated variations in the gas-gain had a small effect on separation until they reached 30% of the total gain.

References

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