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# The performance of the AMS-02 Transition Radiation Detector

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The Alpha Magnetic Spectrometer (AMS-02) [1] is scheduled for flight on board of the International Space Station (ISS) for measurements of the cosmic ray spectrum up to the TeV energy range. It includes a Transition Radiation Detector (TRD) for the identification of electrons and positrons in the range of 1-300 GeV. The expected proton rejection is $10^2$ -$10^3$ with the TRD alone and can be increased up to $10^5$ together with the calorimeter. This proton rejection at an electron efficiency of 90% will be an important asset for the indirect Dark Matter search via an anomalous positron fraction from the Dark Matter annihilation. Funded by the german space agency (DLR): DLR Funding Contract 50OO0505.

## 1. Introduction

Data on high energy electron and positron fluxes have been obtained with the balloon experiment HEAT and a short precursor shuttle flight of AMS-01 [2, 3]. The positron fraction $e^+/(e^+ + e^-)$ is sensitive to the galactic propagation model [4, 5] where electrons are considered as primary particles generated in the supernovae explosions and positrons are the secondary particles appearing from proton interactions with the galactic gas. The deviation from this scenario can be a hint for new physics and particularly the relic Dark Matter (DM) annihilation in our galaxy. The stable products of this annihilation may contribute significantly to the cosmic ray fluxes at higher energies, since heavy cold DM particles will annihilate at rest, so the mass is transformed into kinetic energy of the decay products yielding a deviation from the background prediction at high energies. Indeed, the HEAT data on the positron fraction show a small excess at high energies over the background, predicted by the GALPROP model [4], as shown in Fig. 1. The excess can be explained by the annihilation of a neutralino of about 340 GeV [6, 7]. However, the high energy data was obtained with three short balloon flights of the HEAT detector, so the data is statistically limited. Here AMS-02 will be able to improve significantly, as shown in Fig. 1. The acceptance of AMS-02 for different particles is defined by the geometrical acceptance and the efficiency of particle reconstruction. The right hand side of Fig. 1 shows the simulated acceptances for antiprotons, positrons and gammas together with the background acceptances [8]. For positrons the main backgrounds are protons, which have the same electrical charge, but a factor $10^5$ larger flux. Therefore one needs a proton rejection factor of $>10^5$ in order to see positrons. The electrons can also be misidentified as a positron in case of wrong charge assignment in the tracker; however, the electron flux is only ten times larger than the positron flux. The Transistion Radiation Detector (TRD) and Electromagnetic CALorimeter (ECAL) are the key detectors for electron/positron identification and proton (hadron) rejection. This contribution is focused on the TRD performance. Details on the TRD construction can be found in Ref. [9].

## 2. Electron and Positron measurement with AMS-02

The AMS-02 is a general purpose spectrometer and consists of:

1. the Transition Radiation Detector (TRD) with 20 layers of proportional gas tubes each interleaved with fleece radiator.

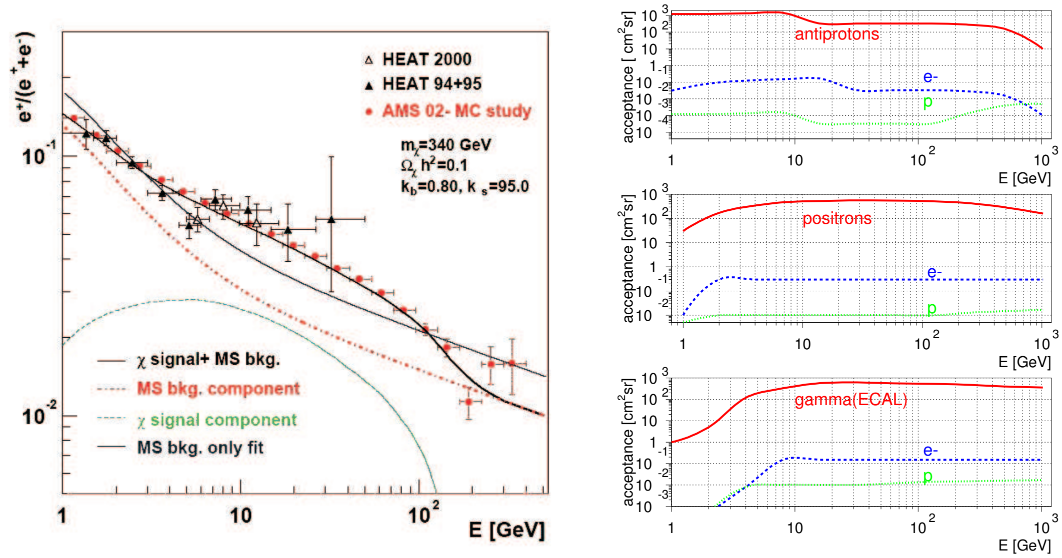


**Figure 1.** The $e^+/(e^+ + e^-)$-fraction after one year of AMS-02 on the ISS in comparison with the data from the HEAT balloon experiment [2]. The ratio was modeled with the background from the GALPROP model [4, 5] and a DM annihilation signal of a 340 GeV neutralino [6]. The acceptance and the main contaminations for the AMS-02 detector [8] are shown on the right for some particles of interest for DM detection.

2. eight layers of silicon tracker inside a superconducting magnet with a maximum dipole field of 0.87 T.

3. the ring imaging Cherenkov detector (RICH) to measure velocities up to 20 GeV.

4. the electromagnetic calorimeter (ECAL) at the bottom of AMS-02, that measures lepton energies and provides lepton/hadron rejection of about $10^3$ up to 1 TeV.

5. the Time of Flight (ToF) and veto scintillator hodoscope to provide a trigger, vetos and velocity measurements.

As mentioned in the Introduction, this note concentrates on the TRD performance. The physical principle of the TRD is based on the radiation of X-ray photons (TR) with energies in the 1-50 keV range which are emitted if a particle crosses the boundary between two media with a different dielectric constant $\epsilon$. The TR energy is proportional to the relativistic $\gamma$-factor and the TR photon number can be increased by using multiple transitions, i.e. multilayer structures. Fig. 2 shows the total energy deposition in 20 TRD layers for electrons and protons; the peaks are clearly separated.

The performance of the AMS-02 TRD detector has been studied with a 20 layer prototype in test beams with electrons and protons and with Monte Carlo (MC) simulations. A Geant3 and Geant4 model [10] were used and tuned to reproduce the test beam data and improve rejection. The first algorithm considered a simple cluster counting method (counting the number of hits above 6.5 keV), but this yielded a relatively poor proton rejection (below 100 for energies above 200 GeV). Therefore a more sophisticated likelihood method was choosen [11], where the geometric mean $P_{e,p}^{mean} = \sqrt[n]{\prod_{k=1}^{n} P_{e,p}^{k}(E_{dep})}$ of probabilities for all n hits was calculated to build the likelihood $L_e$ for the event to be electron like: $L_e = P_e^{mean}/(P_e^{mean} + P_p^{mean})$. The $-\ln(L_e)$ for each $e^-$

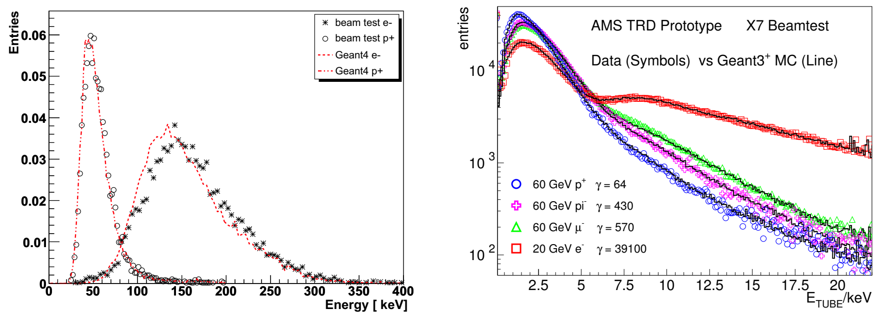


**Figure 2.** The left side shows the total energy deposition in 20 TRD layers for 20 GeV electrons and 100 GeV protons. A large $\gamma$-factor of about 40000 for the electrons compared to the small one of about 100 for the protons allows a clear separation. The test beam data are in reasonable agreement with the predictions of Geant4. TRD single layer spectra for different particles can be seen on the right side. Geant3 is also in good agreement with the test beam data. The different $\gamma$-factors of the particles lead to different TR contributions.

and $p^+$ -sample (for a given energy) were histogrammed. A cut on the distribution of the $e^-$-sample for 90% $e^-$-efficiency applied to the distribution of the $p^+$-sample gave the fraction $N_{p,mis}$ of misidentified $p^+$. With the total number of $p^+$ per sample with $N_{p,tot}$ protons the rejection factor was then defined as $N_{p,tot}/N_{p,mis}$.

The first simulation results with a Geant3 model [11] showed a disagreement between simulation and data at proton energies above 200 GeV: the rejection in real data was considerably lower than predicted by the simulation. This problem was solved by including the quasi elastic diffractive proton process $p + p \rightarrow (p + \pi^+ + \pi^-) + p$ with an adjusted cross section of $\sigma_{diff}$= 15 mb. The $\pi^+ + \pi^-$ pairs were produced with fixed energies of 40 MeV and emitted along the proton direction, thus producing more ionization and increasing the probability to fake TR of a relativistic electron. Geant4 [10] provides an XTR model [12] which is based on a theoretical formulation with parameters to adjust the process for irregular radiator structures like fleeces (used for AMS-02). Geant3 uses a parametrisation of the radiation process with tables generated by a seperate program modelling irregular foil radiators. Moreover the Geant4 hadronic part is completly updated and includes many new processes and cross sections.

A comparison of the proton rejections derived by Geant4, Geant3 and the test beam data is presented in Fig. 3. The discrepancies at high energy occur for Geant4 in the same way as for the former Geant3 model, suggesting that also in Geant4 a process like diffractive scattering has to be added.

## 3. Summary

AMS-02 will be able to measure positron and electron spectra in a range of 1-300 GeV. The AMS-02 TRD will provide a proton rejection $>10^2$ for all energies and above 1000 for energies below 100 GeV. The latter energy range is the one of interest for indirect DM detection, if the hints from the existing data are correct, but also the range above 100 GeV is needed to exclude other origins for an excess in AMS-02 data. The AMS-02 Monte Carlo model is continuously improving and therefore the backgrounds will be better determined, which will lead to more efficient analysis methods with higher proton rejection factors. The much more sophisticated Geant4 model still suffers the same deficiencies as the former Geant3 model concerning the misidentification between protons and positrons at high energies. In Geant3 this could be solved by including an effective

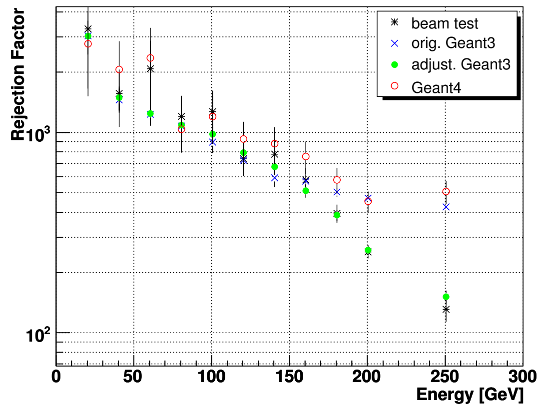


**Figure 3.** The rejection factor of protons for a 90% electron efficiency for the test beam data (points) as function of the beam energy. The orignal Geant3 and Geant4 rejection factor are clearly too optimistic at high energies, while the adjusted Geant3 including an effective diffractive proton-proton scattering describes the data.

diffractive proton-proton scattering as high as 15 mb. Since Geant4 does not include diffractive scattering, a similar approach may be needed here.

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