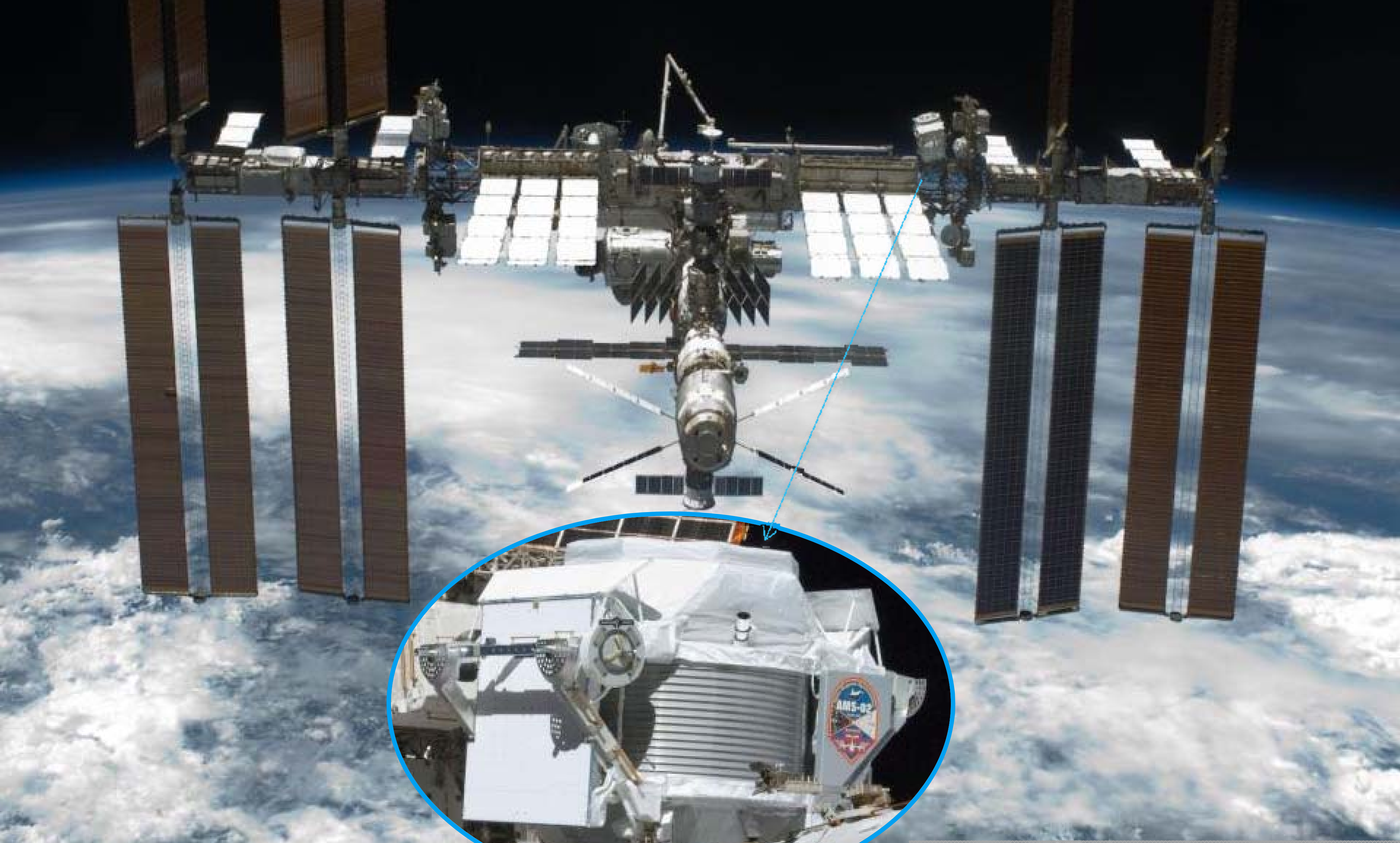
The Alpha Magnetic Spectrometer on the International Space Station



September 2, 2016

D. Son on behalf of AMS

The Alpha Magnetic Spectrometer (AMS) on the International Space Station

AMS is a precision particle physics detector deployed in space to measure charged cosmic rays and study their characteristics.

5m x 4m x 3m
7.5 tons

AMS: A TeV spectrometer

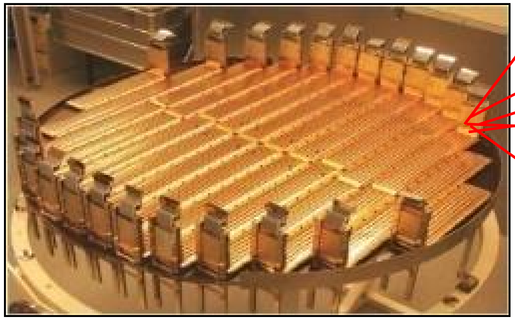
Cosmic rays are characterized by charge (Z) and rigidity (R = P/Z)

Transition Radiation Detector

Identify e^+, e^-

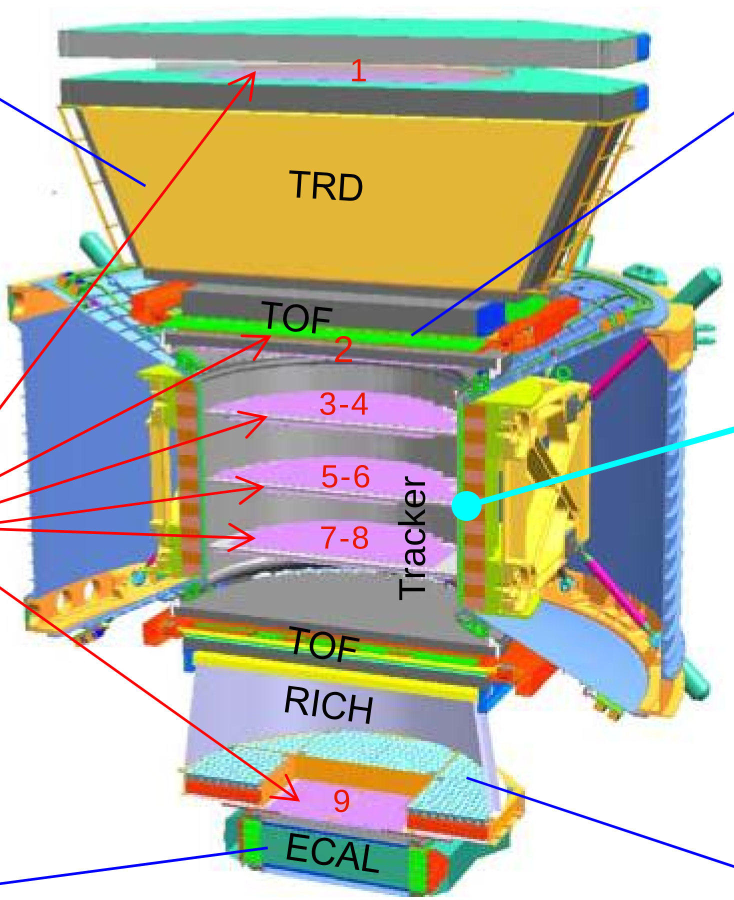
Silicon Tracker

Z, R



Electromagnetic Calorimeter

E of e^+, e^-



Time of Flight

Z, E

Magnet

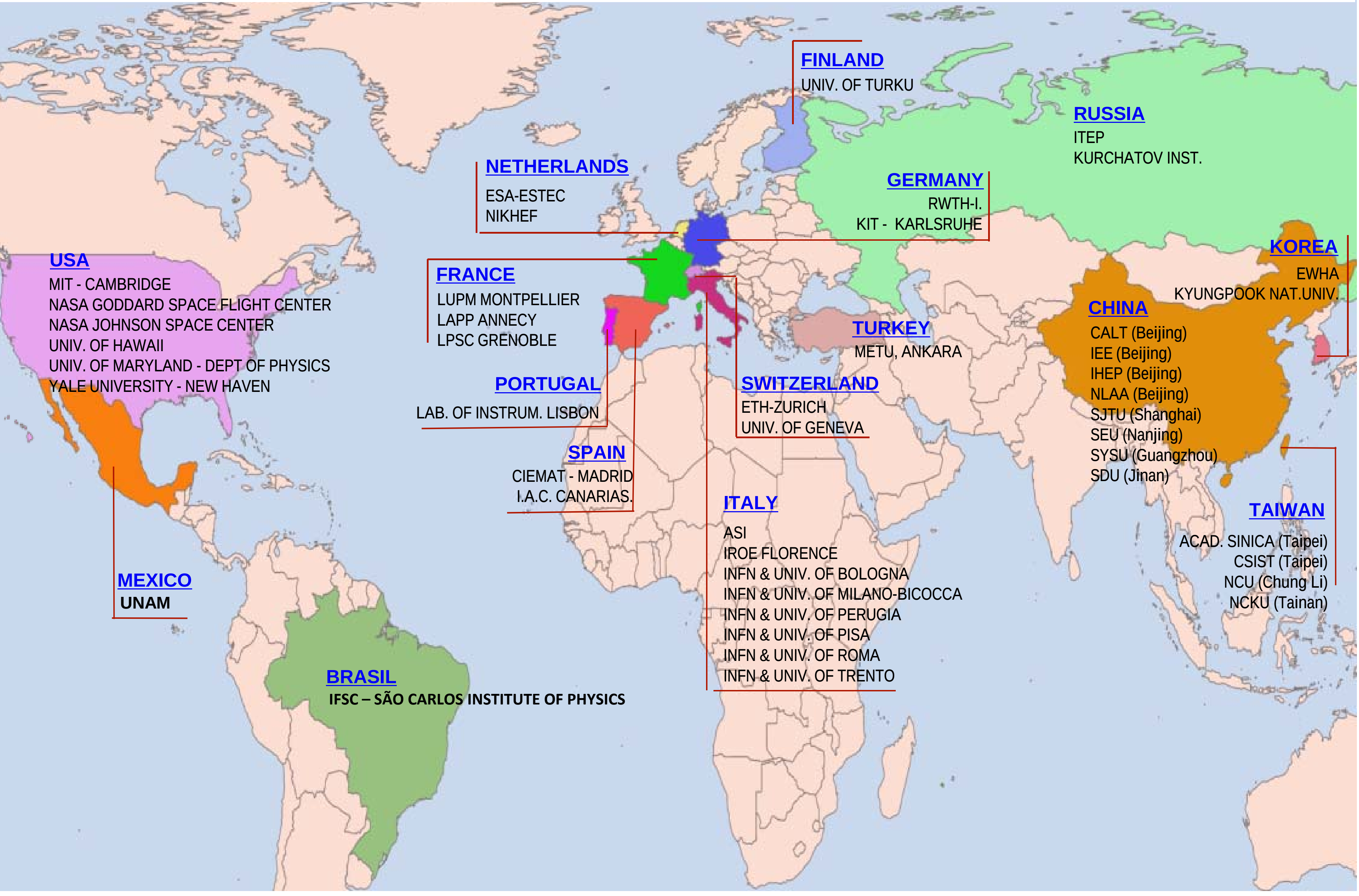
±Z

Ring Imaging Cherenkov

Z, E

Z and R are measured independently by the Tracker, RICH, TOF and ECAL

AMS: an International Collaboration
15 Countries, 46 Institutes and 600 Physicists

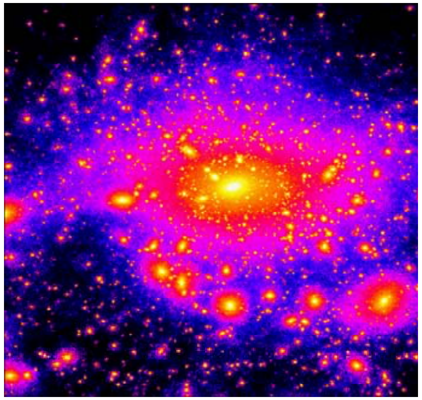


In 5 years on ISS, AMS has collected over 80 billion cosmic rays; much more than all the cosmic rays collected in the last century.

Examples of Physics Results

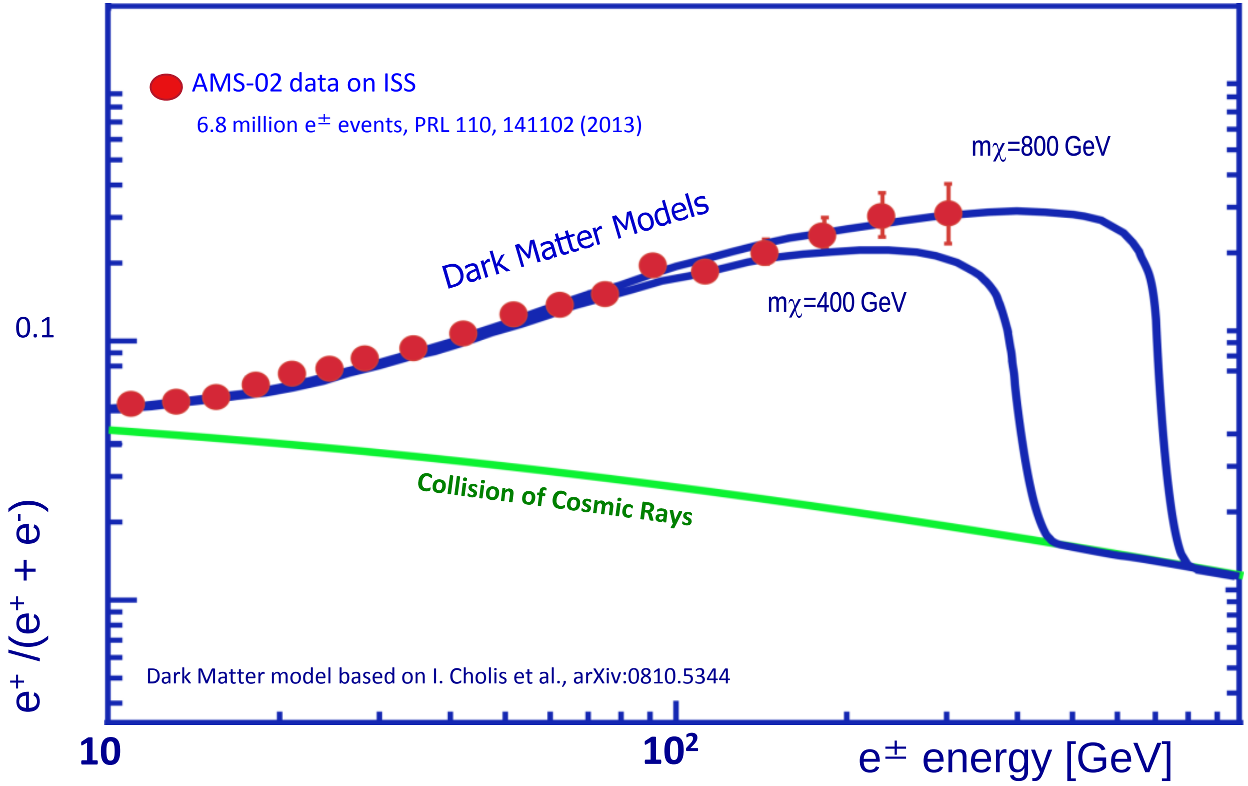
To Search for the Origin of Dark Matter

A Galaxy as seen by telescope



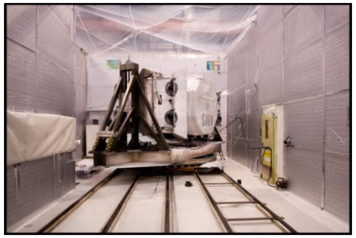
If we could see Dark Matter in the Galaxy

Collisions of Dark Matter (χ) produce energy which turns into ordinary matter, such as e+.



The New York Times — Space & Cosmos

Tantalizing New Clues Into the Mysteries of Dark Matter



Fred Merz for The New York Times

The Alpha Magnetic Spectrometer under construction in 2010 at the European Organization for Nuclear Research in Geneva.

By DENNIS OVERBYE
Published: April 3, 2013

The dark side of the universe is whispering, but scientists are still not sure what it is saying.

Samuel Ting, a professor at the Massachusetts Institute of Technology and a Nobel laureate particle physicist, said Wednesday that his $1.6 billion cosmic ray experiment on the International Space Station had found evidence of "new physical phenomena" that could represent dark matter, the mysterious stuff that serves as the gravitational foundation for galaxies and whose identification would rewrite some of the laws of physics.

The results, he said, confirmed previous reports that local interstellar space is crackling with an unexplained abundance of high energy particles, especially positrons, the antimatter version of the familiar electrons that comprise electricity and chemistry. They could be colliding particles of dark matter. Or they could be coming from previously undiscovered pulsars or other astronomical monsters, throwing off wild winds of radiation.

THE WALL STREET JOURNAL.

U.S. NEWS
Updated April 3, 2013, 6:50 p.m. ET

Hint of Dark Matter Found

By GAUTAM NAIK

The $2 billion particle detector, or AMS, is mounted to the international space station's exterior to gather data.

A space experiment may have identified a new particle that is the building block of dark matter, the mysterious stuff said to pervade a quarter of the universe that neither emits nor absorbs light.

The results are based on a small amount of data and are far from definitive, scientists said Wednesday. Yet, they provide a provocative hint that the puzzle of dark matter—a cosmic prize as eagerly sought as the now-discovered Higgs boson—may also be on its way to being solved.

The results are the first obtained by a $2 billion particle detector, known as Alpha Magnetic Spectrometer, or AMS, that is mounted on the exterior of the international space station. It collects and identifies charged cosmic rays arriving from the far reaches of space.

The experiment is sponsored by the U.S. Department of Energy. It is led by Nobel laureate Samuel Ting of the Massachusetts Institute of Technology and involves hundreds of scientists from all over the world. The latest data will be published in the journal Physical Review Letters.

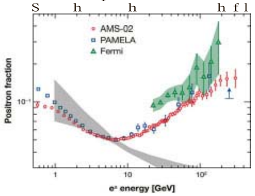
FRANKFURTER ALLGEMEINE ZEITUNG

Natur und Wissenschaft

NR. 83 · SEITE N1
MITTWOCH, 10. APRIL 2013

Antimateriejäger auf der Raumstation

Lange ließ Samuel Ting seine Zuhörer im großen Hörsaal des europäischen Forschungszentrums Cern in Genf am Mittwoch in der vergangenen Woche warten. Der Physik-Nobelpreistäger vom Massachusetts Institute of Technology hat während der vergangenen zwei Jahrzehnte, die er dem Bau des größten je im All betriebenen Teilchendetektors gewidmet hat, gelernt, geduldig zu sein. Da ließ er es sich nicht nehmen, zunächst ausführlich auf die technischen Details des Antimaterie-Spektrometers AMS (Alpha Magnetic Spectrometer) und die bewegten Zeiten einzugehen, die es auf seinem Weg zur Internationalen Raumstation (ISS) durchlebt hat. Dann erst sprach er über die mit Spannung erwarteten ersten Resultate. Eine Sensation konnte Ting allerdings nicht verkünden. Wer Neues in Sachen Dunkle Materie, gar den Nachweis der „Wimps" – jene hypothetischen Teilchen gelten als Kandidaten für die das Universum durchziehende unsichtbare und noch unbekannte Materieform – erwartet hatte, wurde enttäuscht. Selbst von Hinweisen zu sprechen, wäre übertrieben: „Als Experimentalphysiker richten wir uns nach dem, was die Daten sagen." Leider sprechen die Daten eine orakelhafte Sprache, und so kommt es darauf an, wie man sie interpretiert.



Der Anteil der gemessenen Positronen (e^+) in der kosmischen Strahlung als Funktion der Energie (hier logarithmisch aufgetragen). Deutlich zu erkennen ist der noch unerklärliche Überschuss an gemessenen Positronen ab zehn Milliarden Elektronenvolt (GeV). Einen ähnlichen Befund hatten bereits die Weltraumsonden Pamela und Fermi erbracht.

Ein Großexperiment auf der Raumstation: Das Alpha Magnetic Spectrometer AMS ist im Vordergrund zu erkennen. Foto Reu, Nasa

Tatsächlich, so verkündete Ting, hat das Spektrometer nach 18 Monaten im All einen Positronenüberschuss gefunden („Physical Review Letters", Bd. 110, Nr. 141102). Begeisterungsstürme rief diese Nachricht jedoch nicht hervor, schließlich hatte der Satellit „Pamela" bereits vor drei Jahren den gleichen Befund erbracht. Und dem Energiespektrum, das Ting präsentierte, fehlte der erhoffte Knick. Zwar muss es für den signifikanten Positronenüberschuss eine noch unbekannte Quelle geben, aber genauso wahrscheinlich wie die Dunkle Materie – und für viele Experten noch wahrscheinlicher – kommen Pulsare dafür in Frage. Die Sache ist also verzwickt: Weder liefern die Daten von AMS klare Hinweise auf Wimps, noch kann man deren Existenz ausschließen. Eine magere Ausbeute also? Immerhin hat das fünf Meter hohe und sieben Tonnen schwere Spektrometer rund 1,5 Milliarden Euro gekostet. Doch die Klage von der teuren Raumfahrt ist unangebracht. Nie zuvor hat ein derart komplexes Spektrometer die kosmische Strahlung im Weltall untersucht. Mit AMS beginnt die Ära der „Präzisions-Astroteilchenphysik" – vom Stellenwert etwa zu vergleichen mit den beiden Weltraummissionen WMAP und Planck, die Astronomen gerne als den Beginn der Präzisionskosmologie werten (siehe F.A.Z. vom 27. März).

Stefan Schael von der RWTH Aachen und Leiter der deutschen AMS-Gruppe, gibt sich zufrieden: „Wir haben es geschafft, einen Detektor auf die Raumstation zu bringen, der die kosmische Strahlung deutlich präziser vermessen kann als alle Instrumente vorher." Das war keine leichte Aufgabe. Die kosmische Strahlung besteht zu 95 Prozent aus Protonen und Heliumkernen, Positronen enthält sie nur in Spuren. Um die Antielektronen herauszufischen, charakterisiert ein ganzes Arsenal von kleineren Geräten alle durch das AMS-Spektrometer fliegenden Teilchen nach Ladung, Masse und Energie. Schael und seine Kollegen haben dazu ein spezielles Instrument konstruiert, das die positiv geladenen Positronen von den zehntausendfach häufigeren, ebenfalls positiv geladenen Protonen unterscheiden kann. „Wir können ausschließen, dass es sich bei den gemessenen Positronen um fehlinterpretierte Protonen handelt", erklärt Schael: „Das war bei den früheren Experimenten nicht der Fall." Zudem sind in die ersten Ergebnisse gerade einmal acht Prozent des insgesamt zu erwartenden Datenvolumens eingeflossen.

Le Monde
Samedi 6 avril 2013
SCIENCE & TECHNO | ACTUALITÉ

Matière noire ou pulsars ? L'énigme du « chaudron galactique »

ASTROPHYSIQUE | L'expérience AMS embarquée sur la Station spatiale internationale apporte de nouvelles données confirmant que la Voie lactée abrite une source inconnue de particules

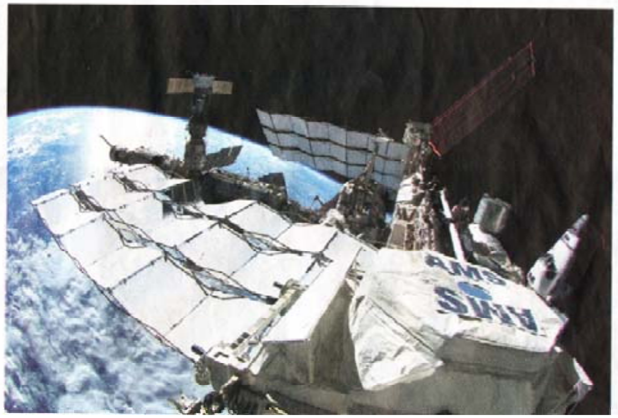
DAVID LAROUSSERIE

Il y a bien quelque chose de bizarre dans notre galaxie. Quelque chose comme un chaudron d'où jailliraient plus de particules que ce que la théorie attendrait. Mais de quoi est fait ce chaudron ?

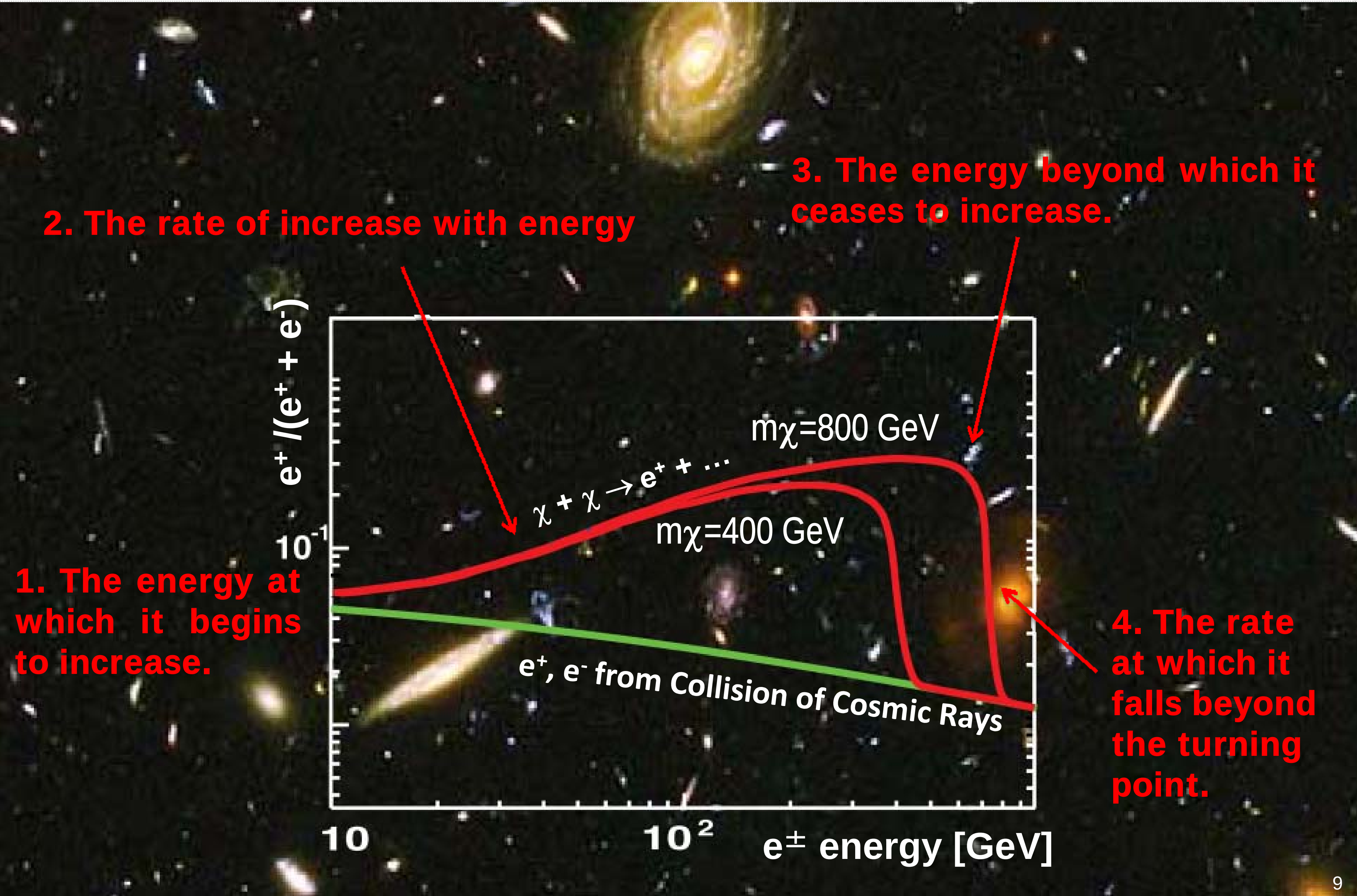
La question était au centre des résultats présentés par le Prix Nobel de physique 1976, Samuel Ting, dans un amphithéâtre de l'Organisation européenne de physique nucléaire (CERN), en Suisse, mercredi 3 avril. Ce chercheur est le porte-parole de l'expérience internationale AMS-02, installée sur la Station spatiale internationale depuis mai 2011 à quelque 350 kilomètres d'altitude. Cet instrument de huit tonnes et demie, fruit d'une collaboration principalement américaine et européenne, détecte l'ensemble des rayons cosmiques comme les électrons, les protons, l'hélium mais aussi leurs antiparticules, sortes de sœurs jumelles de charges électriques opposées, positon, antiproton ou antihélium.

Ces flux de matière constituent ce qu'on appelle les rayons cosmiques, violentes émissions de particules à l'origine d'ailleurs encore inconnue depuis leur détection par Victor Hess en 1912, à bord d'un ballon.

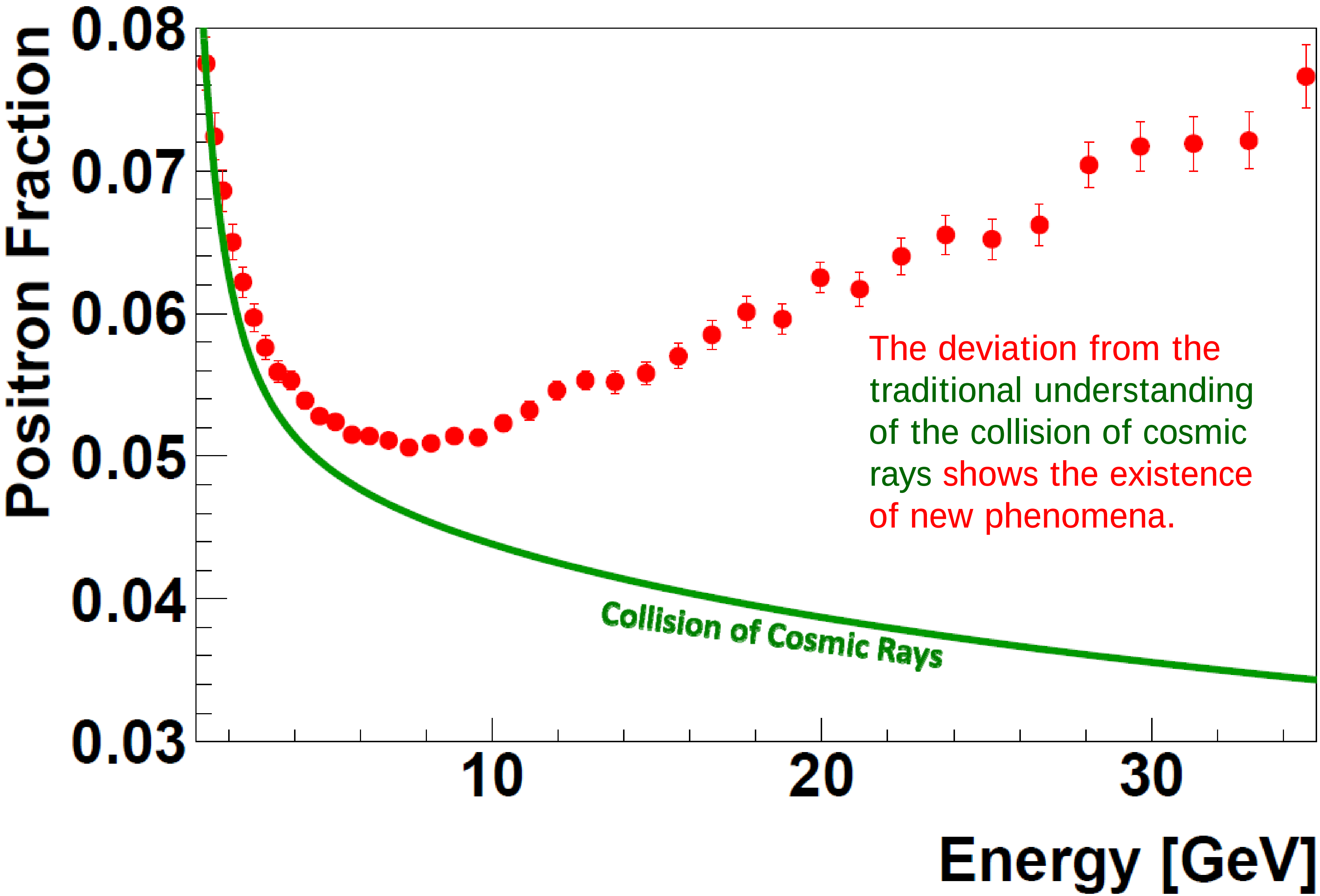
Les dix-huit mois d'enregistrement d'AMS-02 ont permis de voir passer plus de 25 milliards de particules. Et parmi celles-ci, à haute énergie, les chercheurs observent quelque 400 000 antiélectrons, ou positons. Soit un excès d'environ dix fois ce qui était attendu dans des scénarios conventionnels.



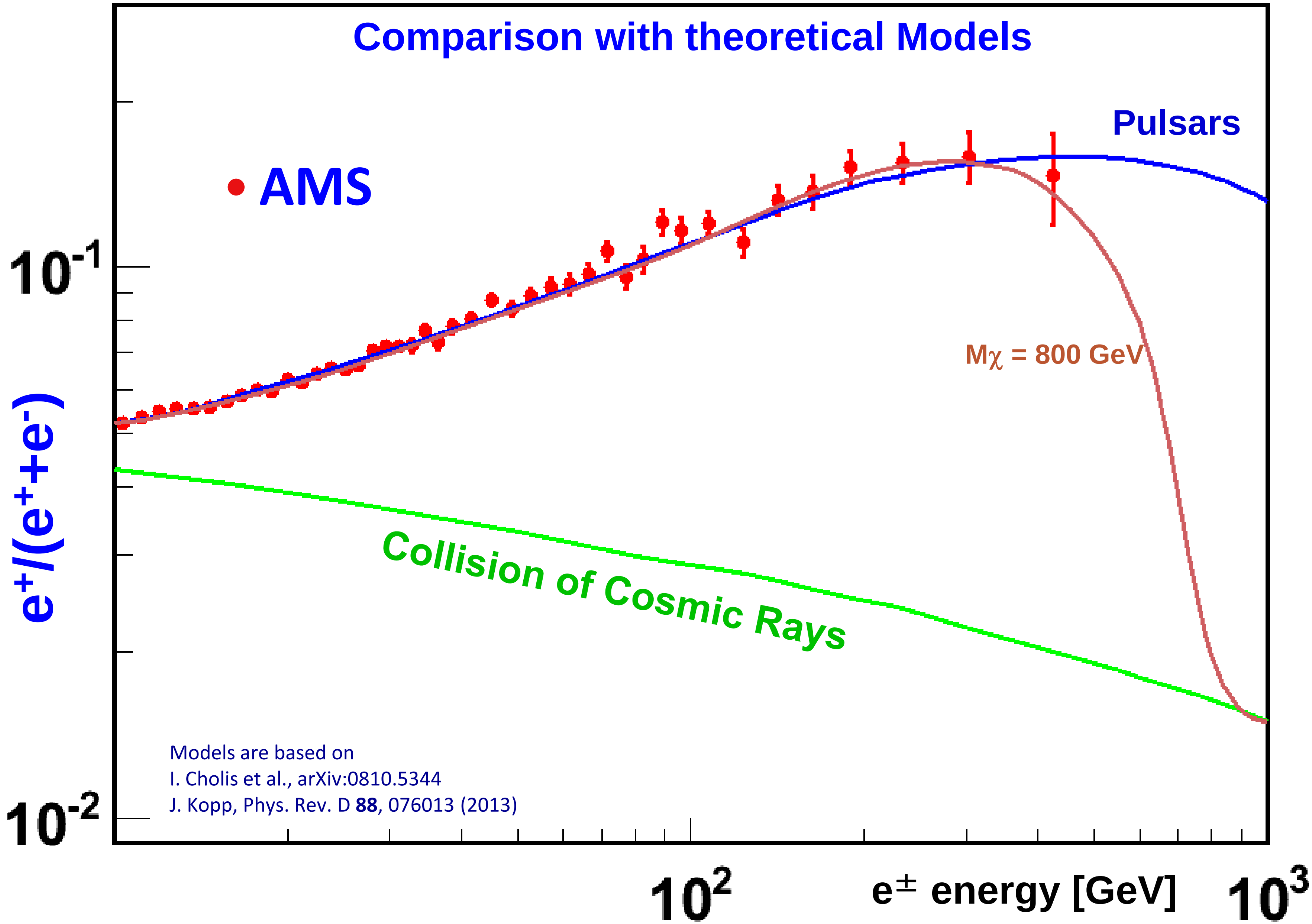
New Results on the Positron Fraction from 11 million events



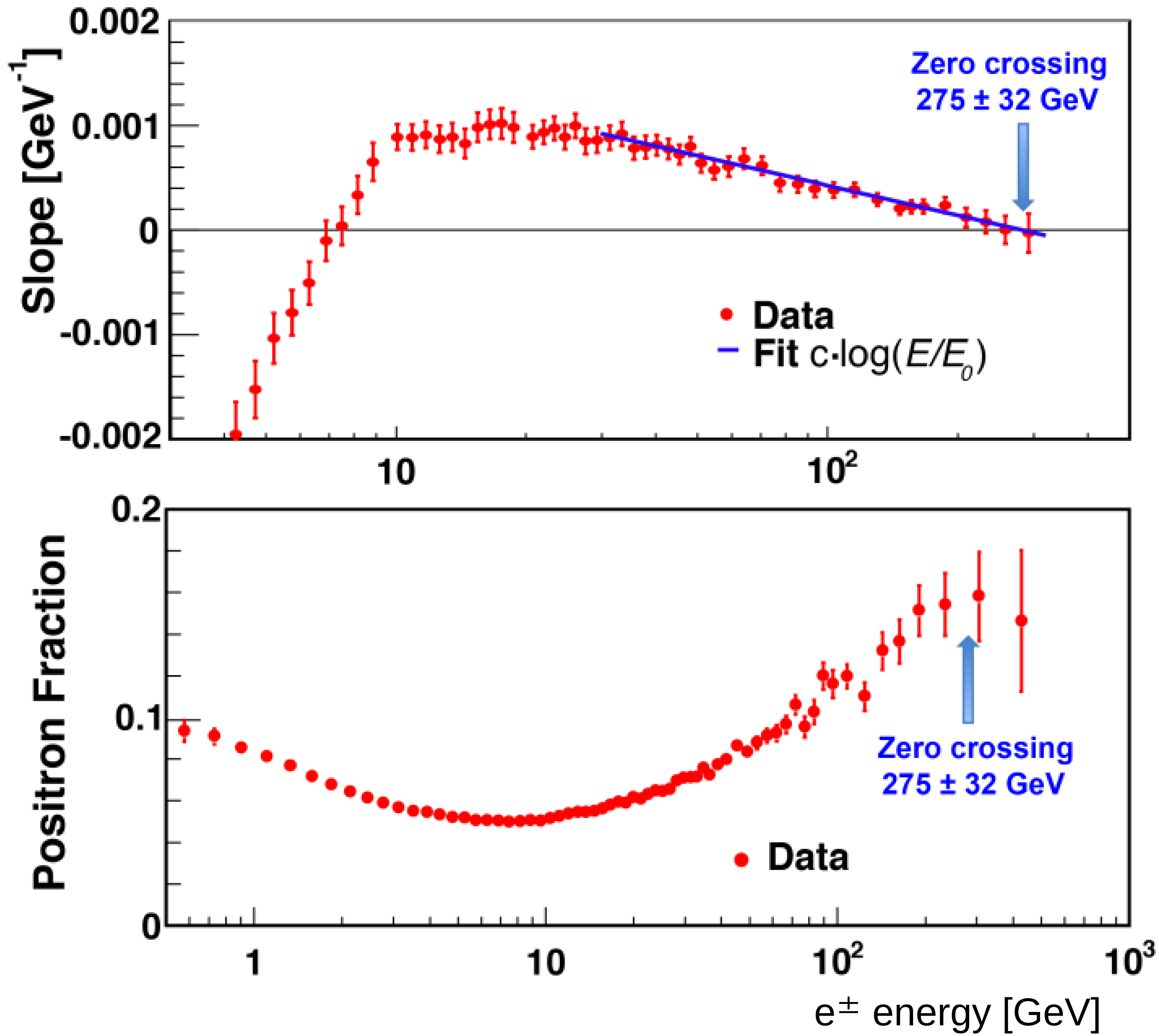
1. The energy at which it begins to increase.



2. The rate of increase with energy.

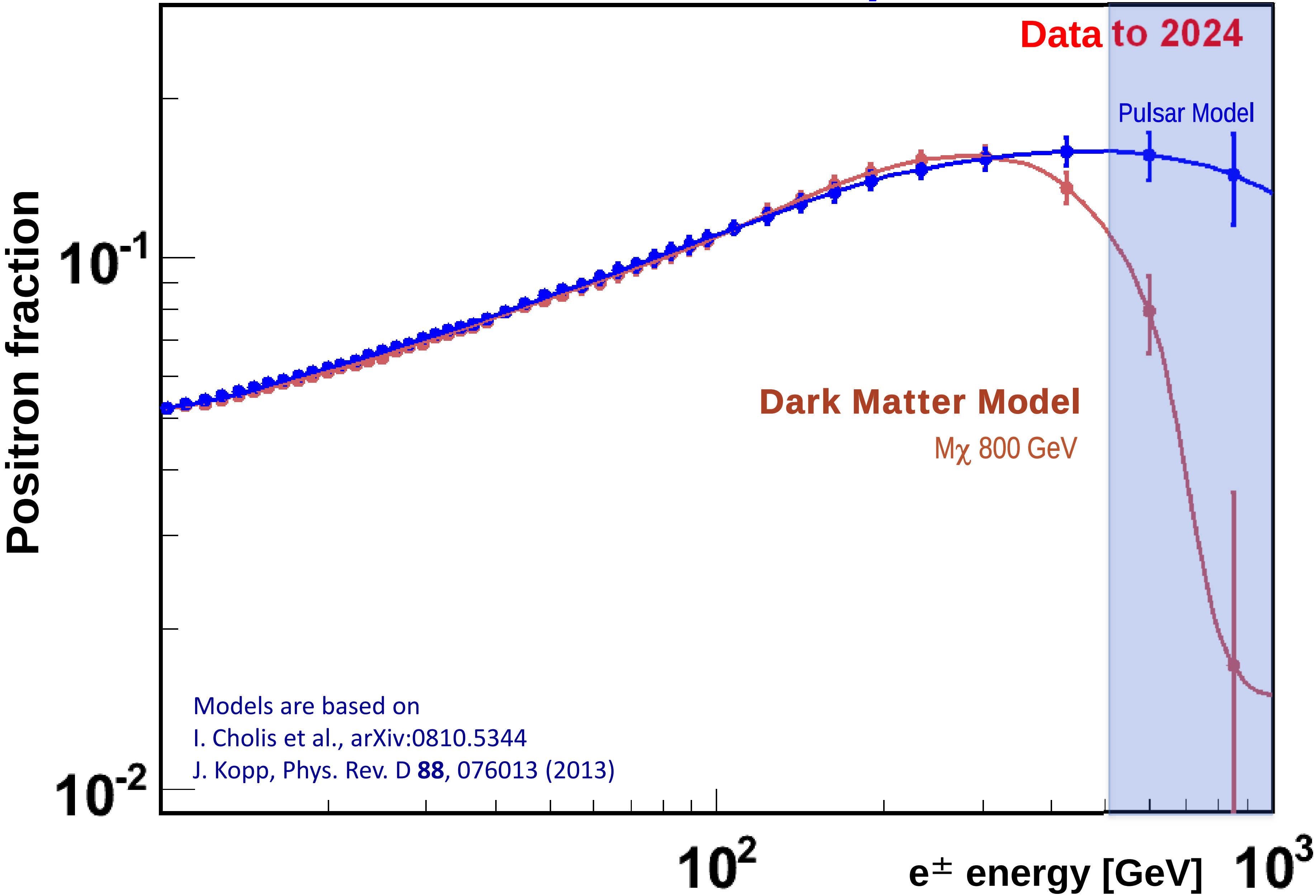


3. The energy beyond which it ceases to increase.

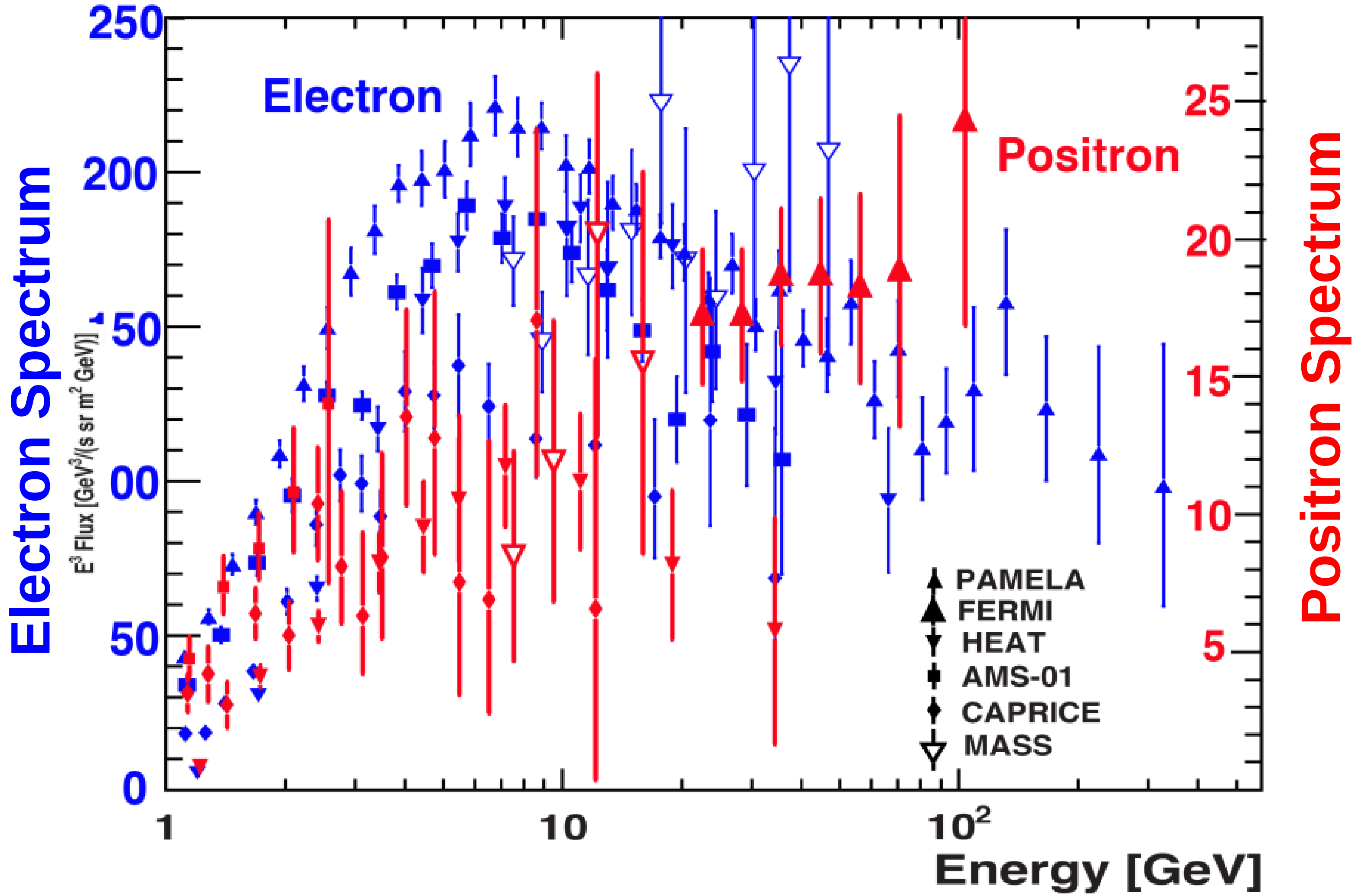


4. The rate at which it falls beyond the turning point.

Positron Fraction Measurement compared with models

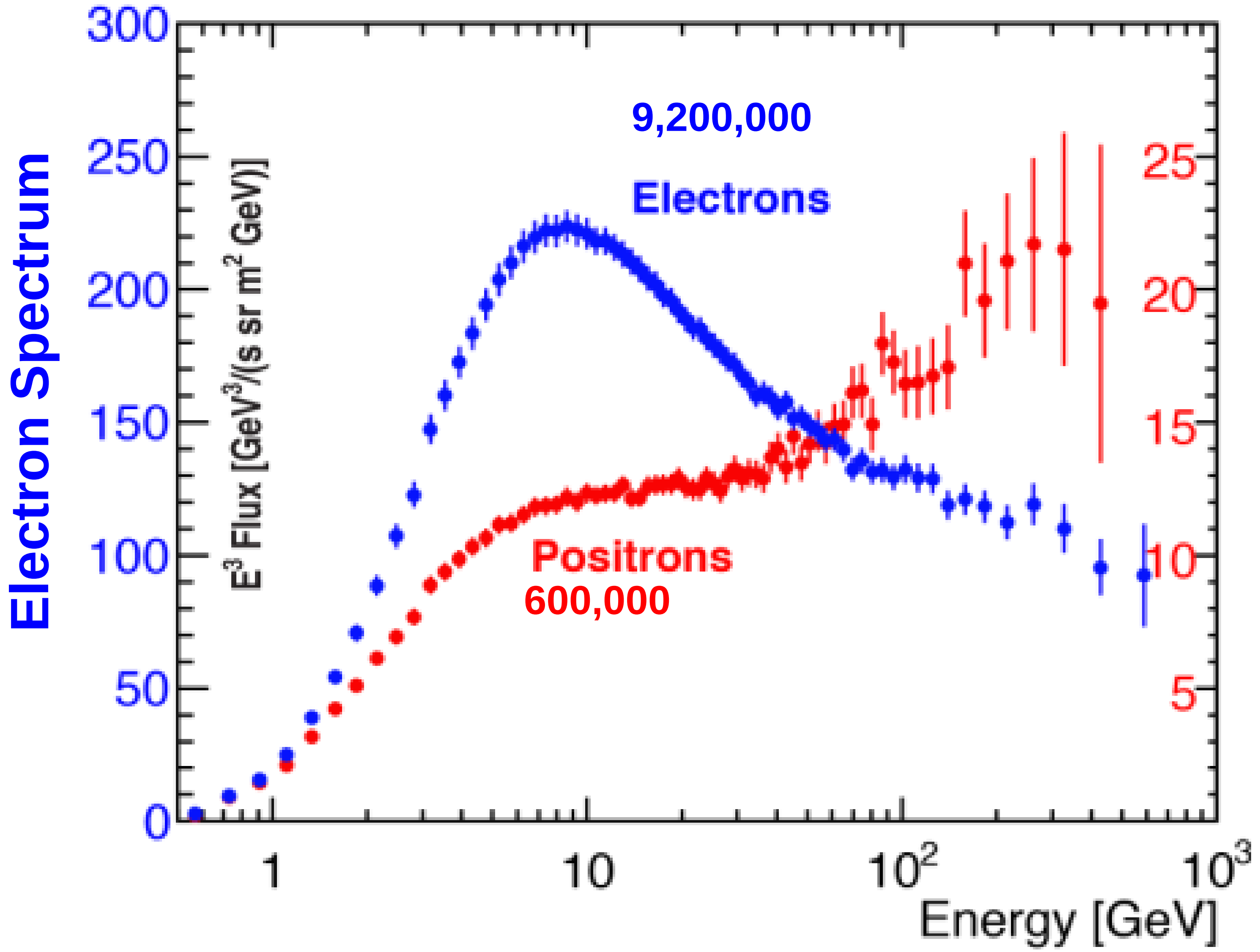


Measurements of Electron and Positron spectra before AMS



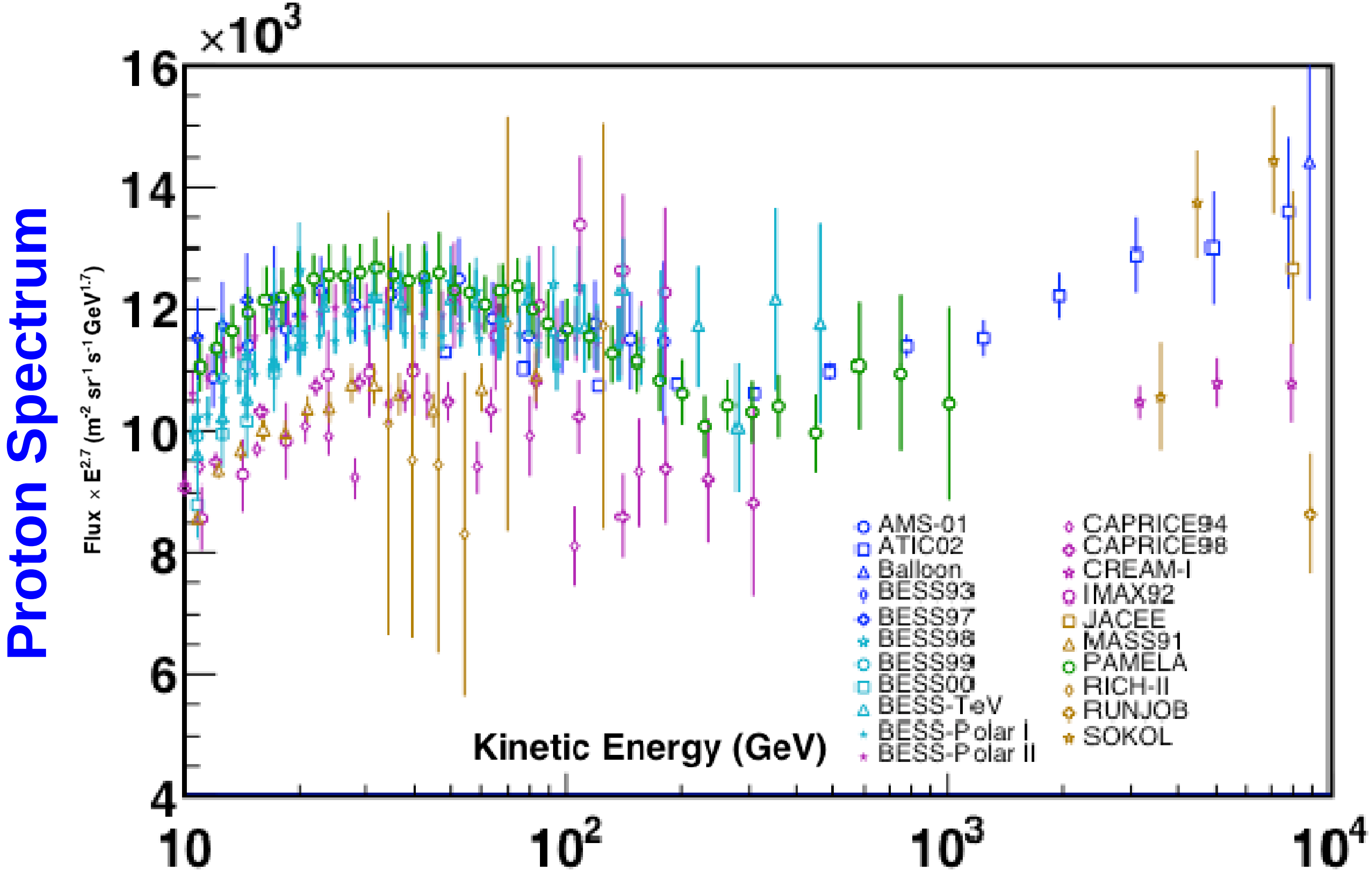
1. These were the best data over the last hundred years.
2. Nonetheless, the data have large errors and are inconsistent.
3. The data has created many theoretical models.

AMS measurements of the Electron and Positron spectra



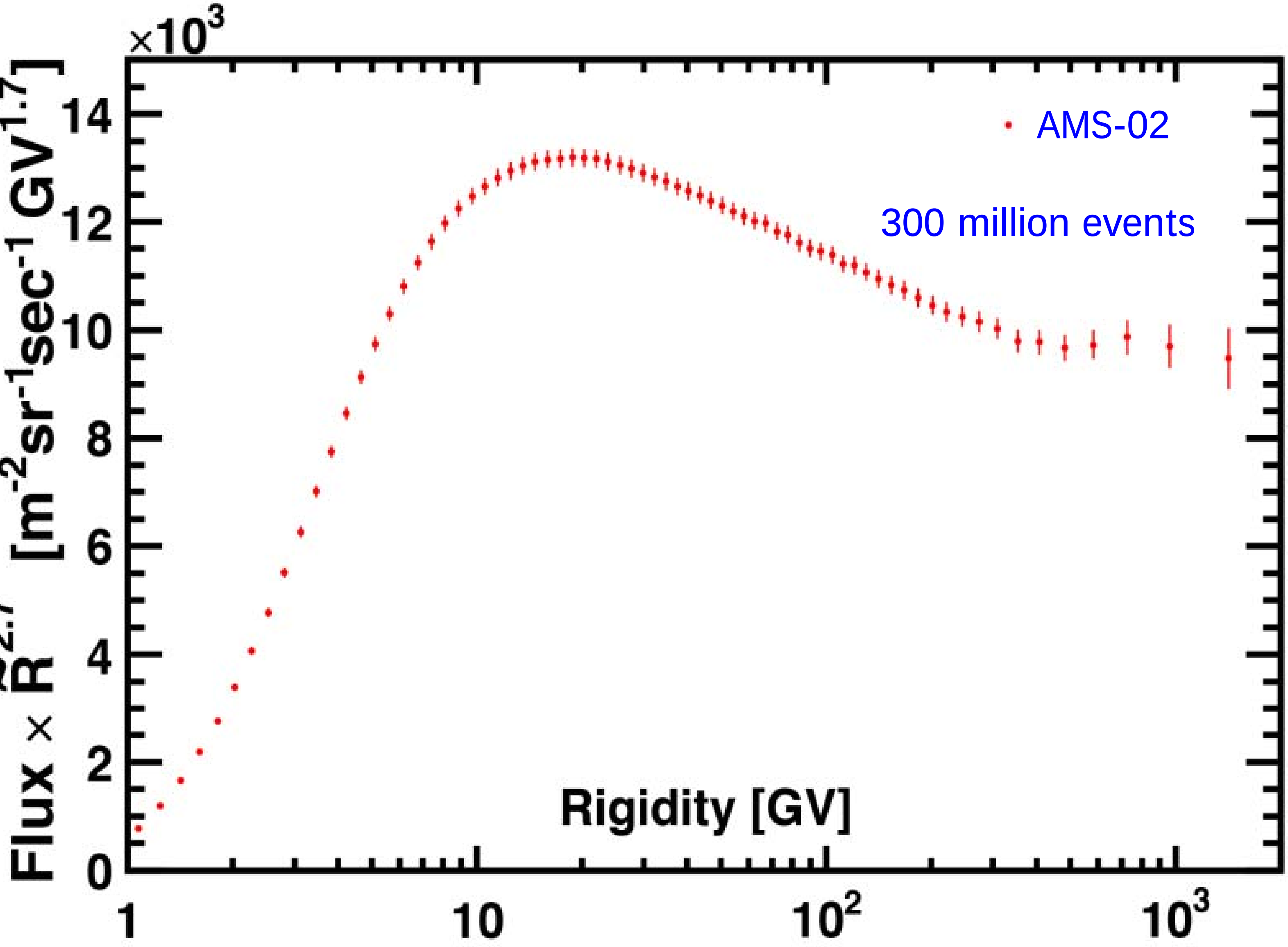
AMS data clearly exhibit the different behavior of the electron and positron spectra both in magnitude and in the energy dependence

Measurements of proton spectrum before AMS



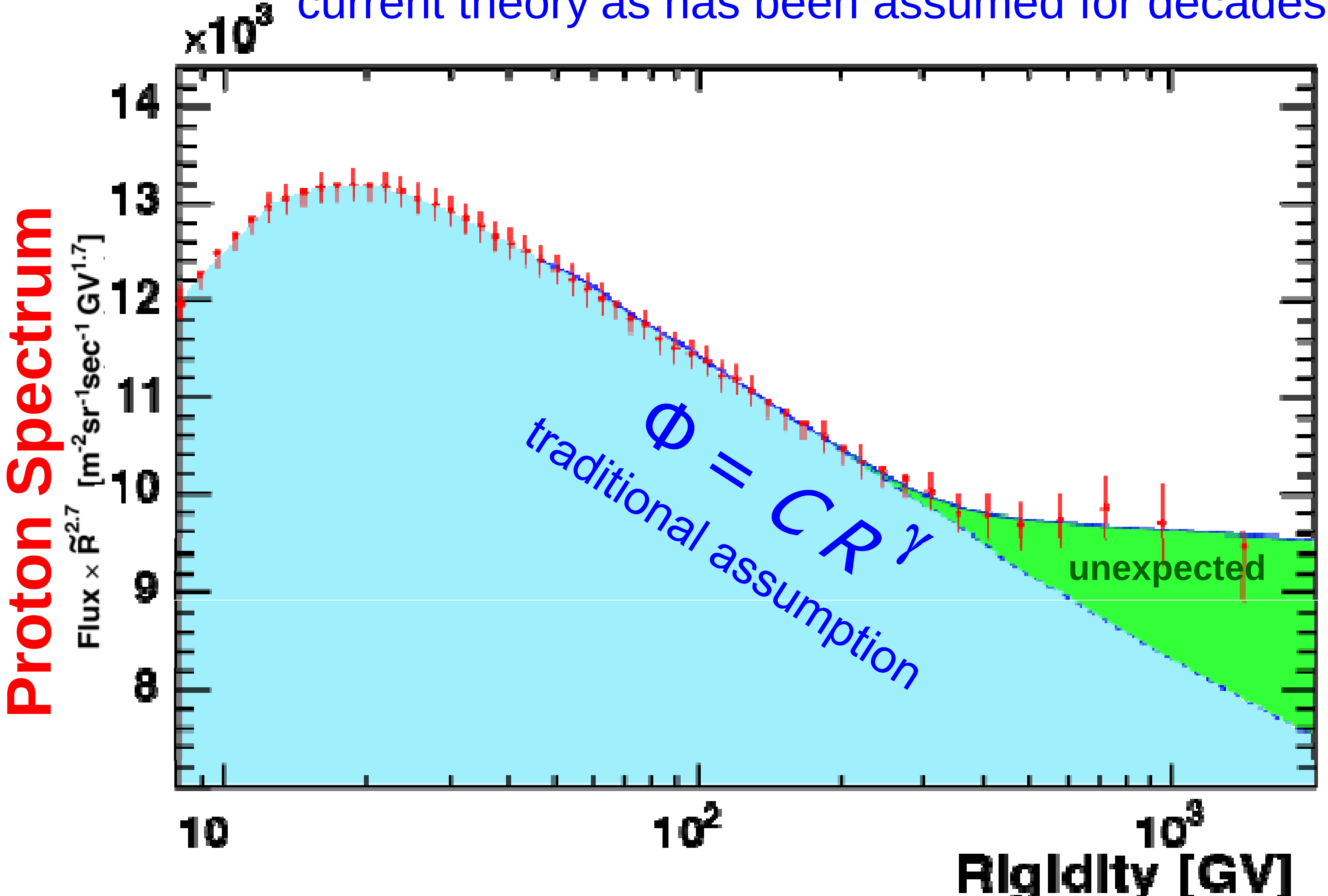
1. Protons are the most abundant cosmic rays.
2. These were the best data over the last hundred years.
3. Nonetheless, the data have large errors and are inconsistent.

AMS proton flux

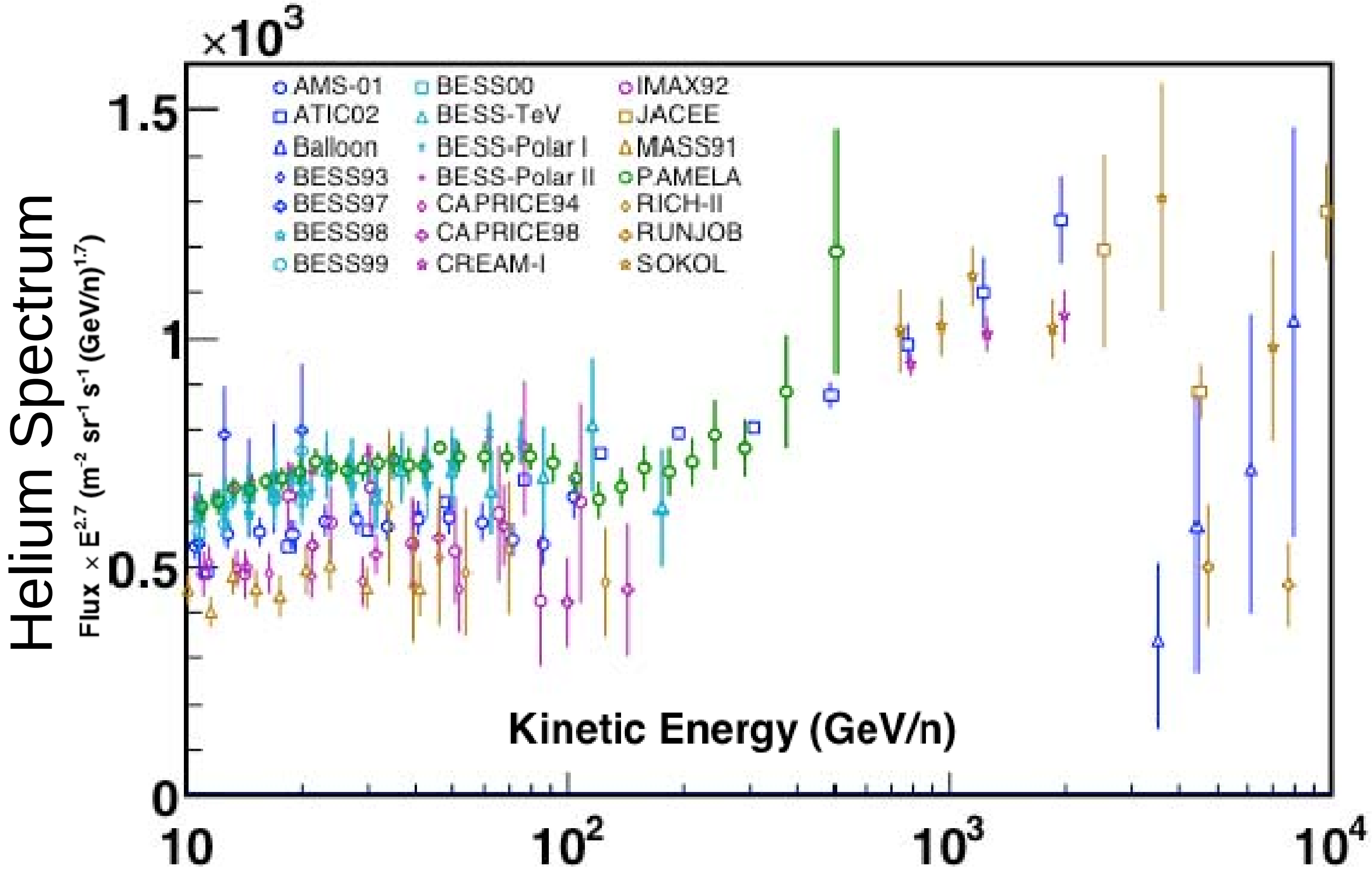


AMS proton flux

New information: The proton flux cannot be described by the current theory as has been assumed for decades

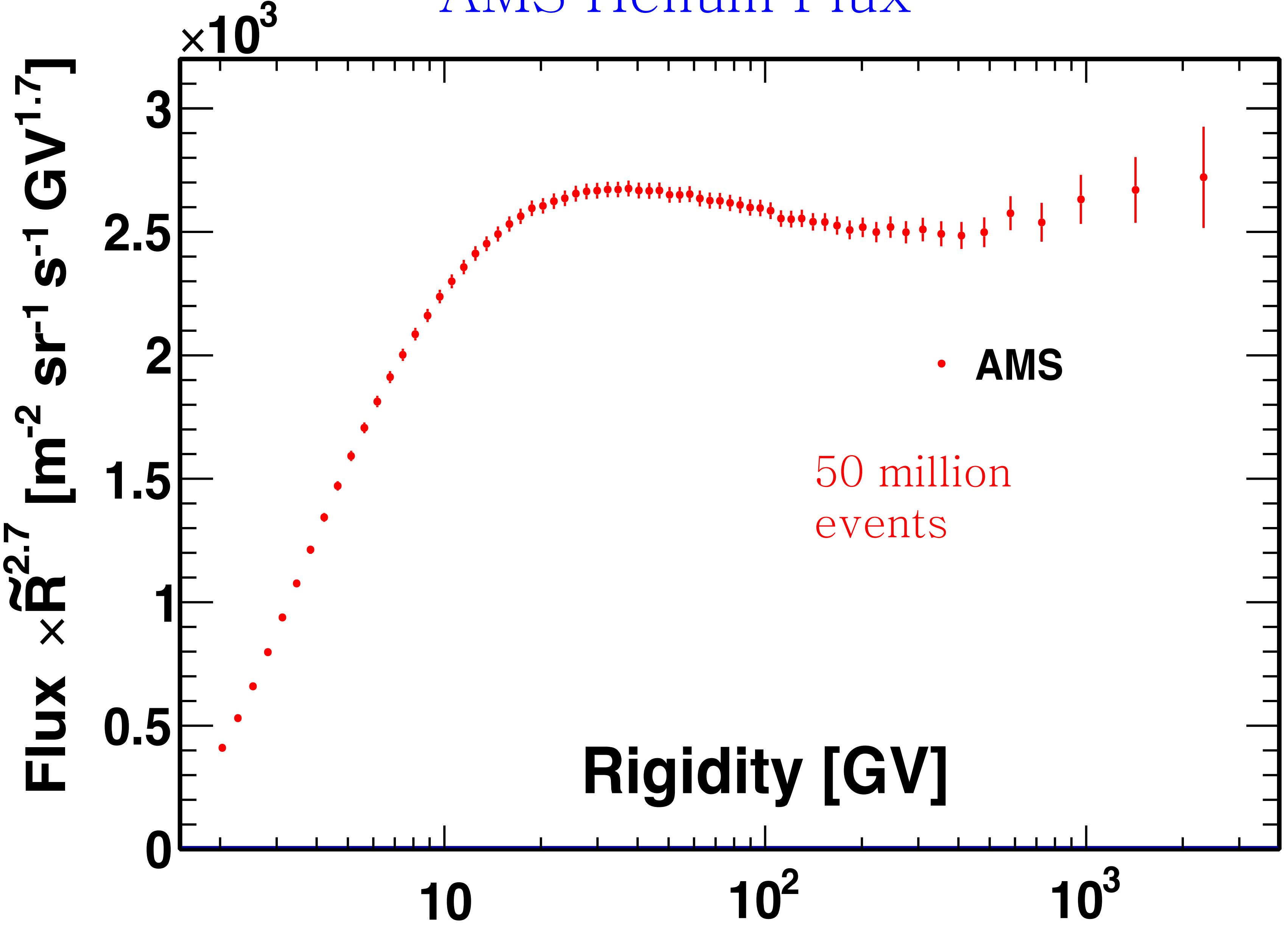


Measurements of helium spectrum before AMS



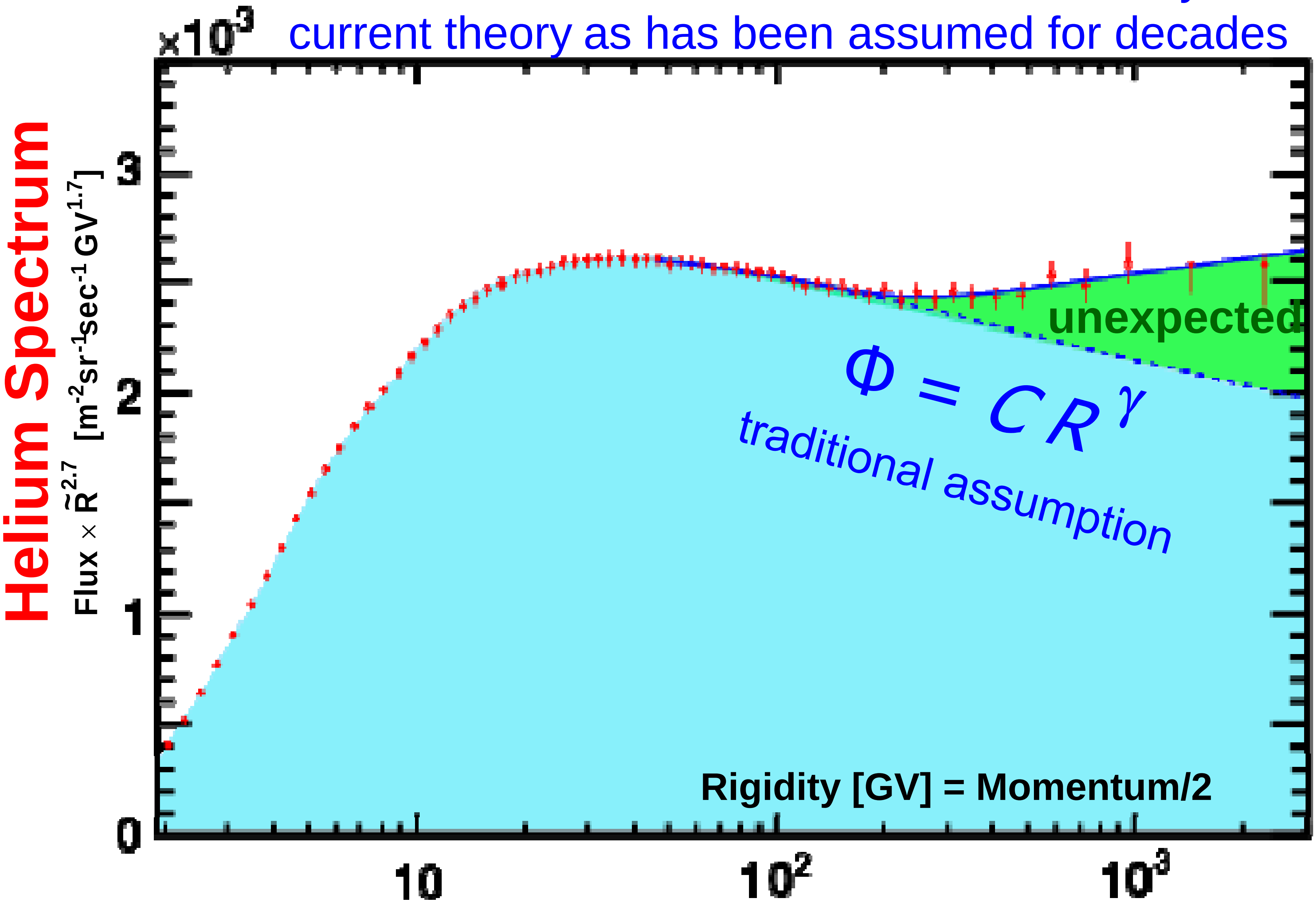
1. Helium are the 2nd most abundant cosmic rays and are mostly produced in supernovas.
2. These were the best data over the last hundred years.
3. Nonetheless, the data have large errors and are inconsistent.

AMS Helium Flux



AMS Helium Flux

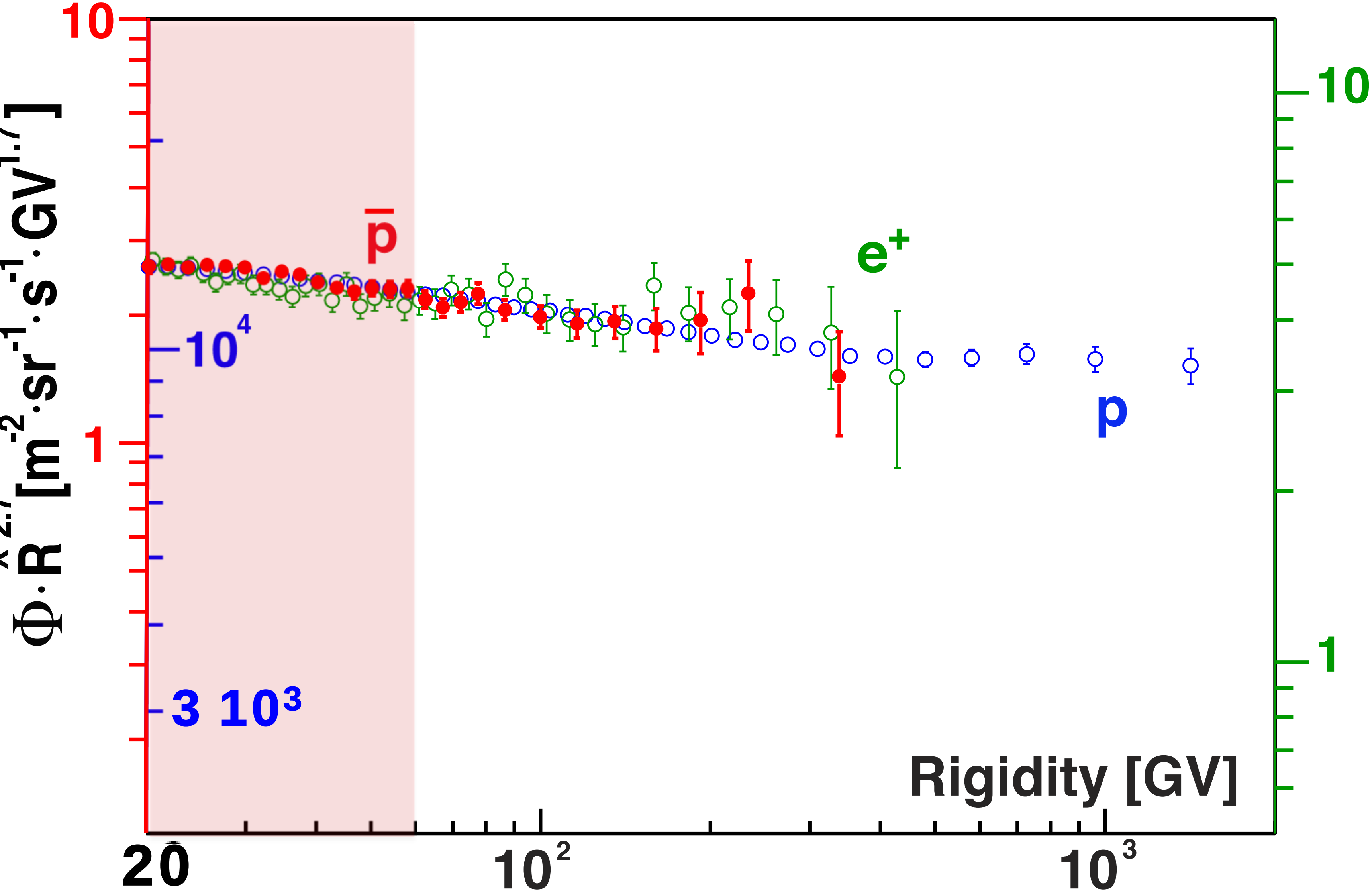
New information: The helium flux cannot be described by the current theory as has been assumed for decades



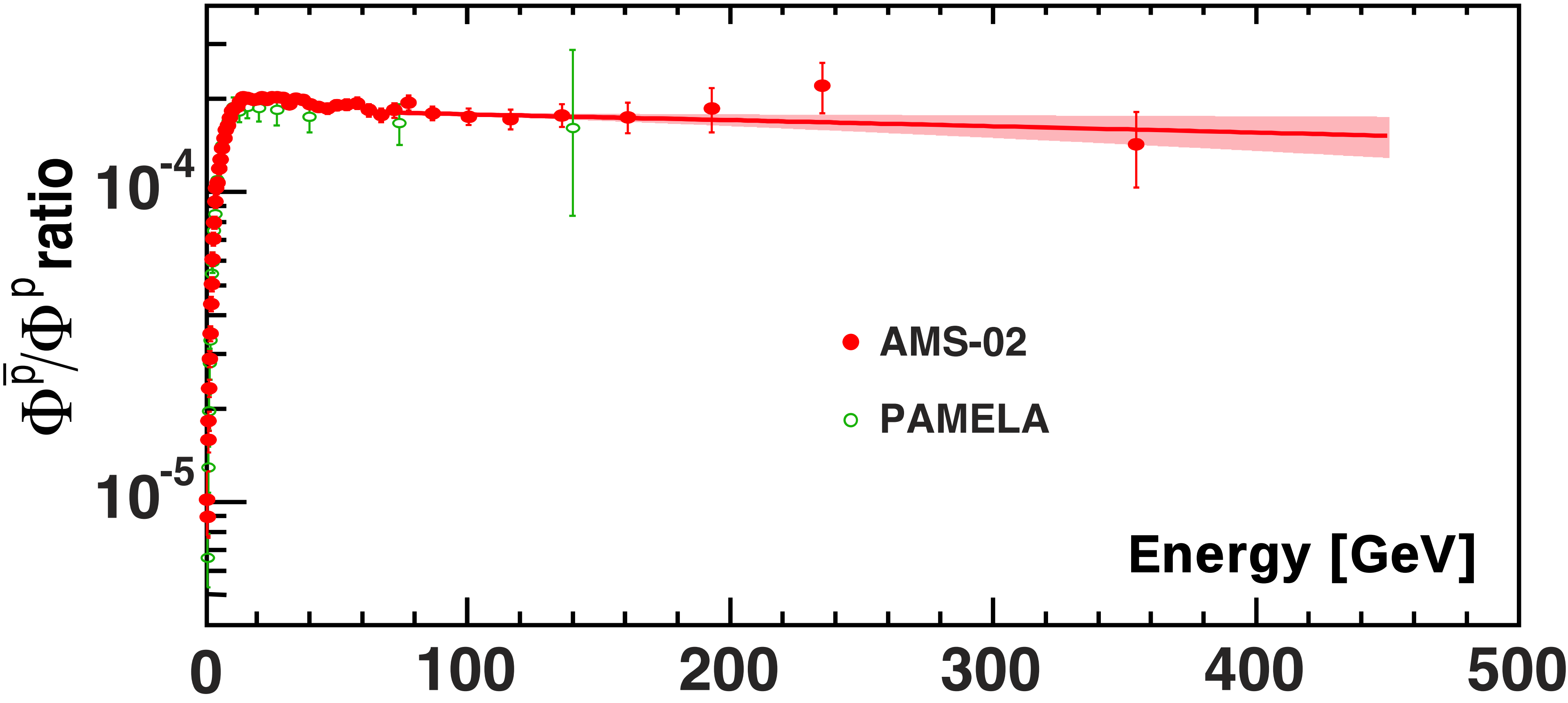
Latest Publication

Unexpected Result

Spectrum of Elementary Particles e^+, $\bar{p}$, p have identical energy dependence above 60 GeV



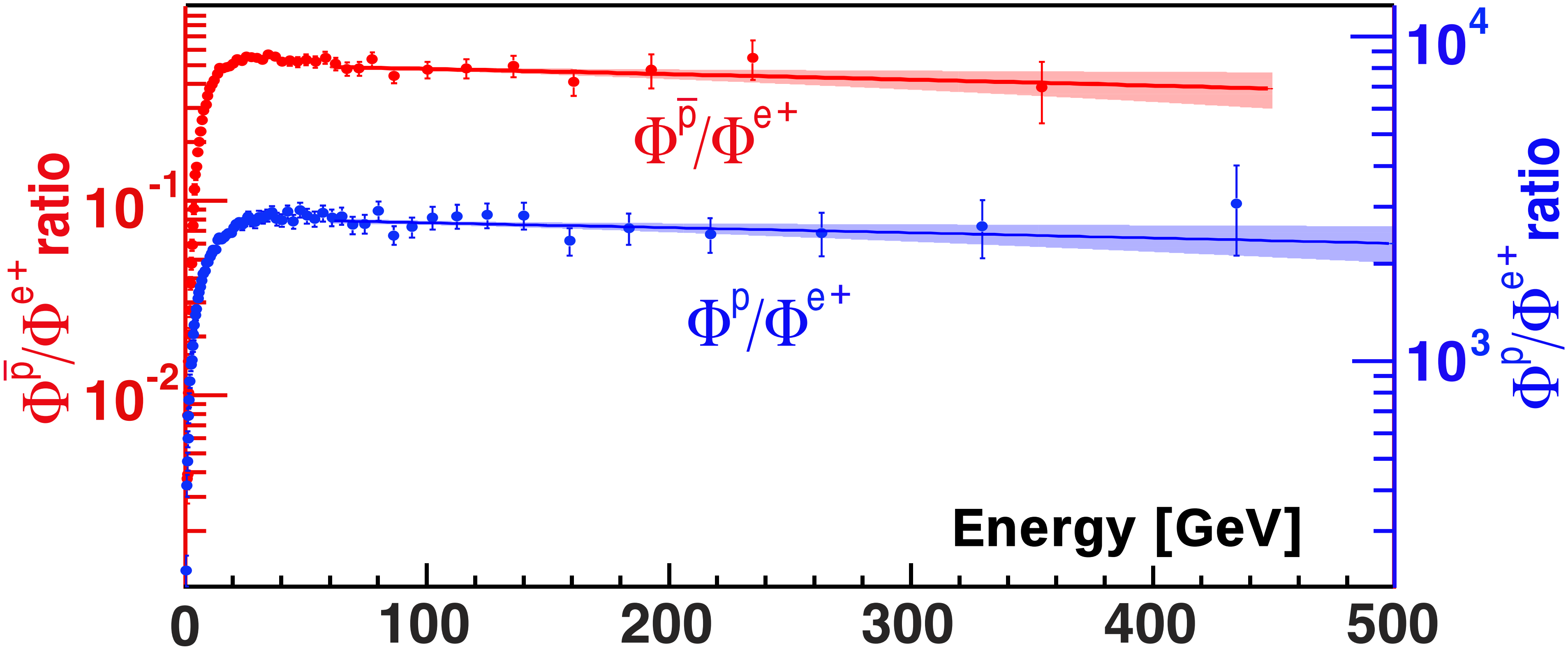
Flux Ratio of Elementary Particles $\bar{p}/p$ is energy independent above 60 GeV



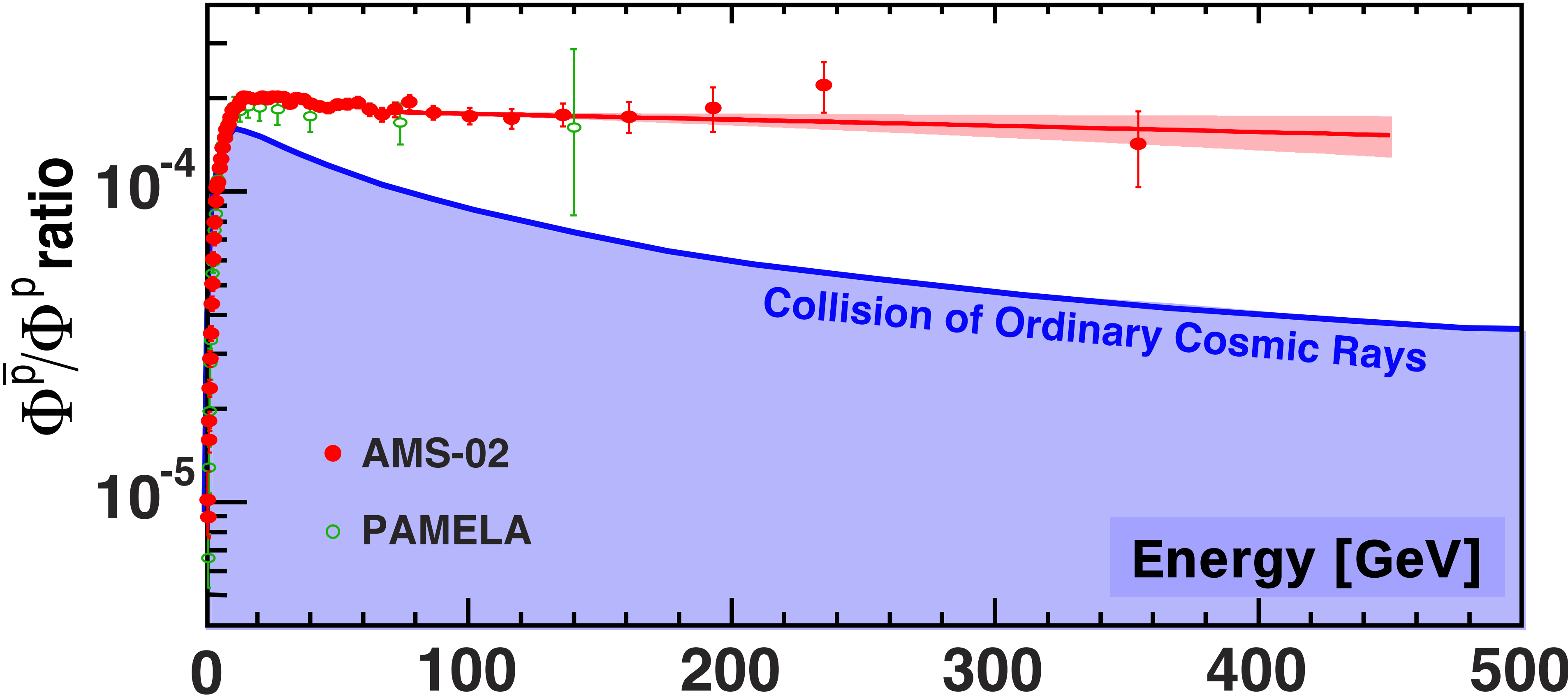
Latest Publication

Unexpected Result

Flux Ratios of Elementary Particles $\bar{p}/e^+$ and p/e^+ are energy independent above 60 GeV



Dark Matter Search $\bar{p}/p$

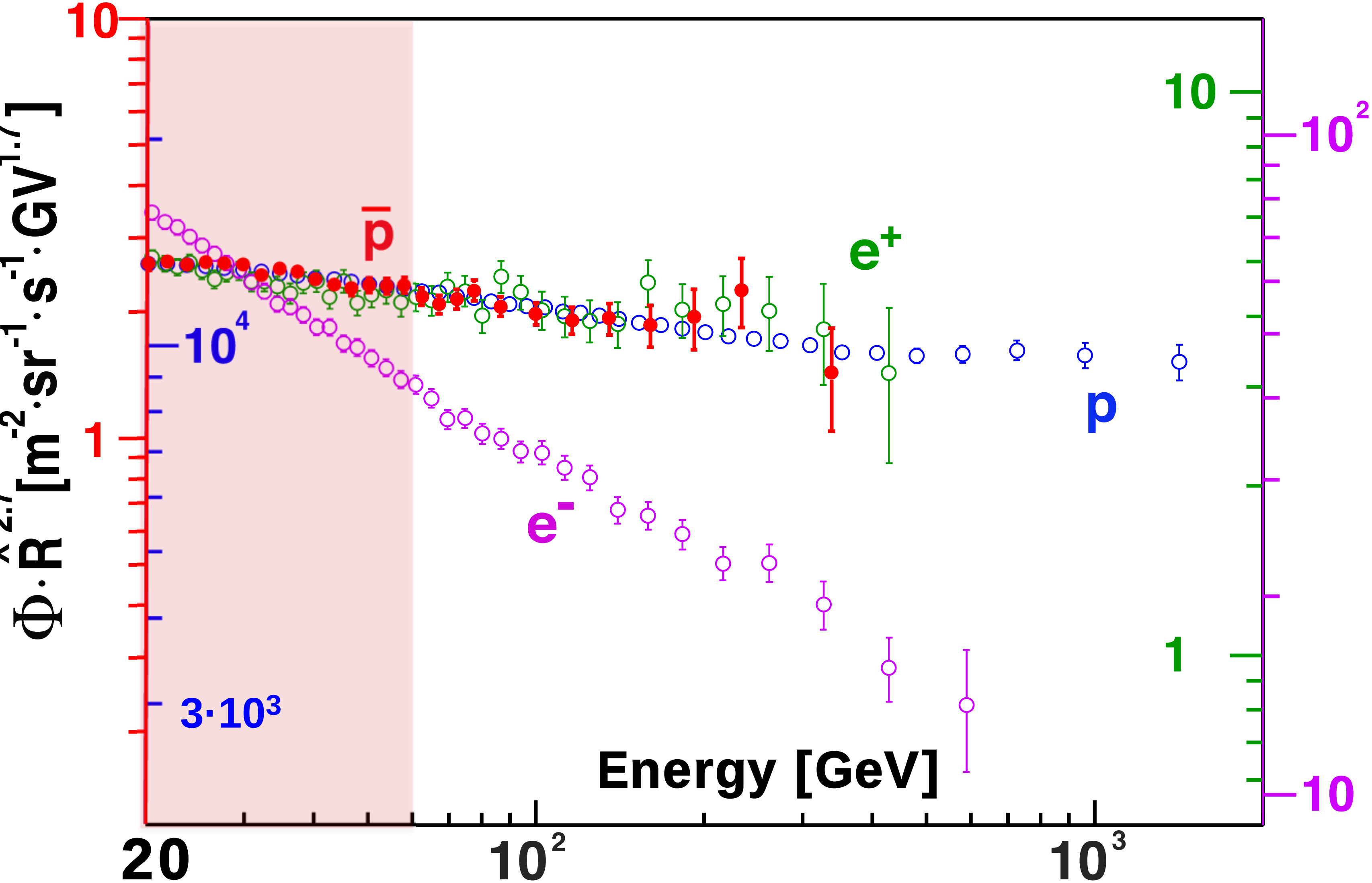


The $\bar{p}/p$ excess cannot come from pulsars

Spectrum of Elementary Particles

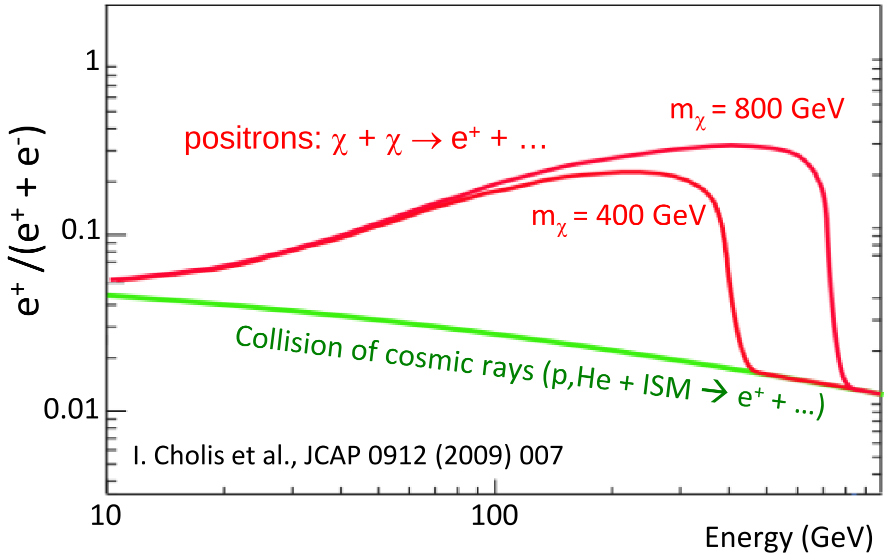
e^+, $\bar{p}$, p have identical energy dependence

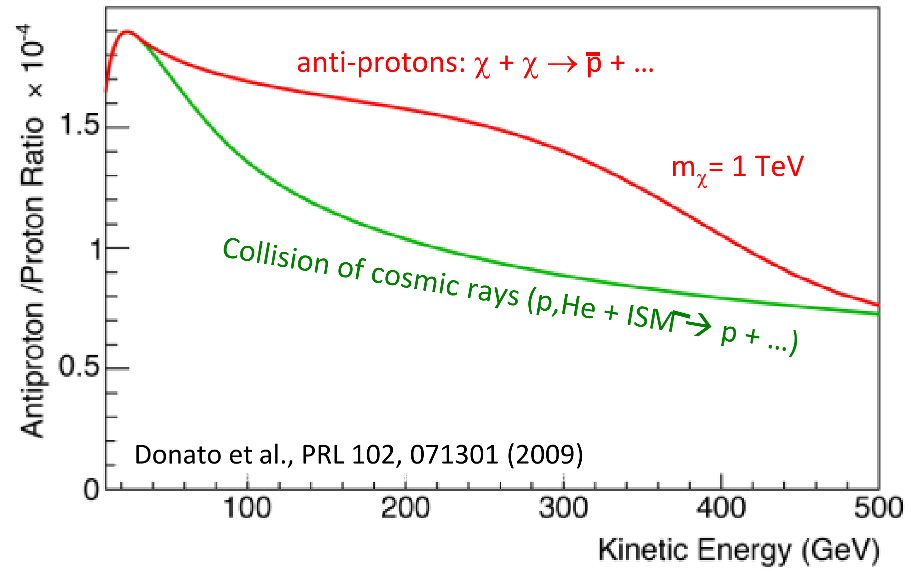
e^- does not



Search for Origin of Dark Matter

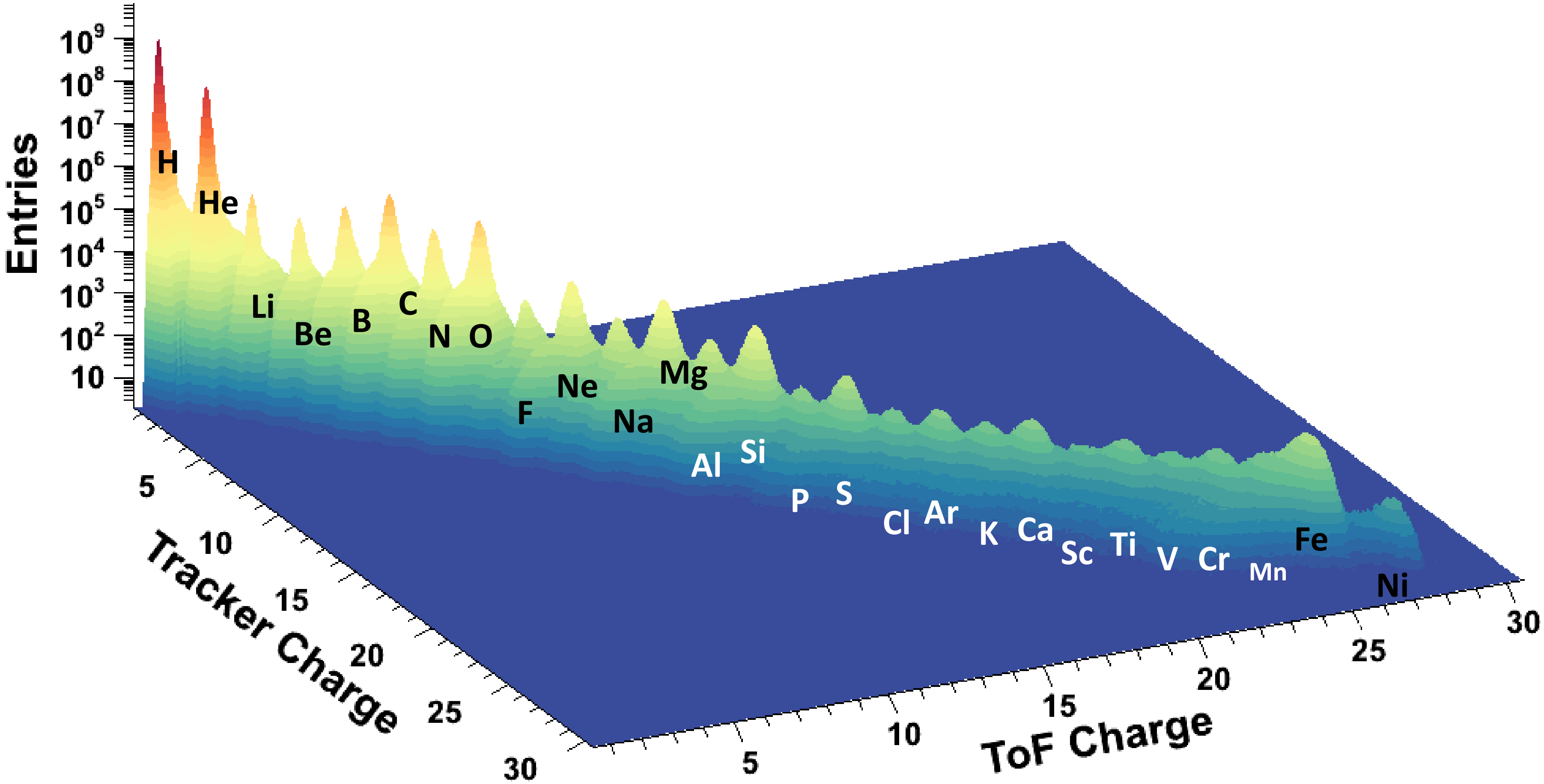
Collisions of Dark Matter particles may produce a signal of e^+, $\bar{p}$, …
detected above the background from the collisions of cosmic rays



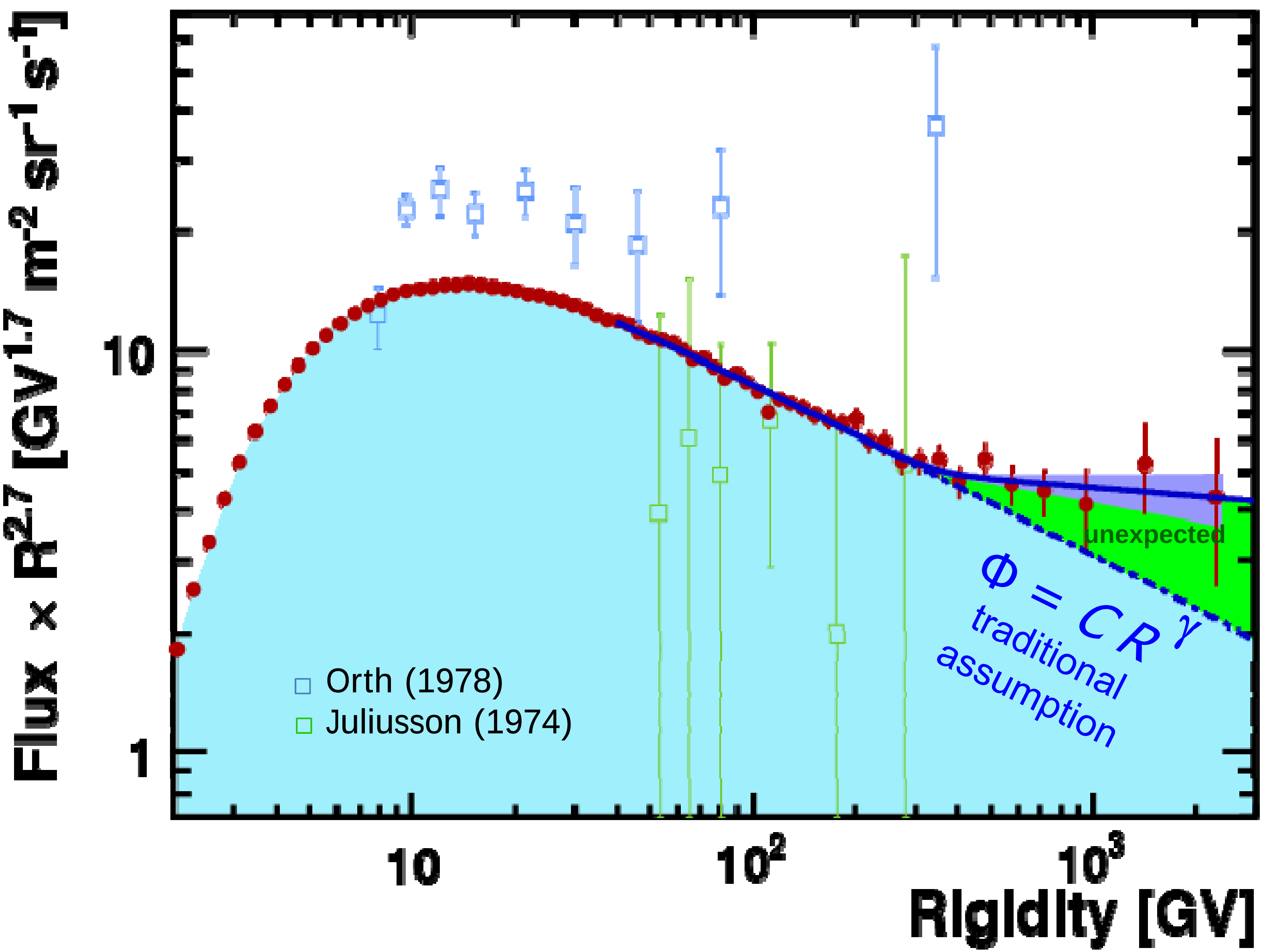


To understand background, we need precise knowledge of the cosmic ray fluxes and their propagation in cosmos

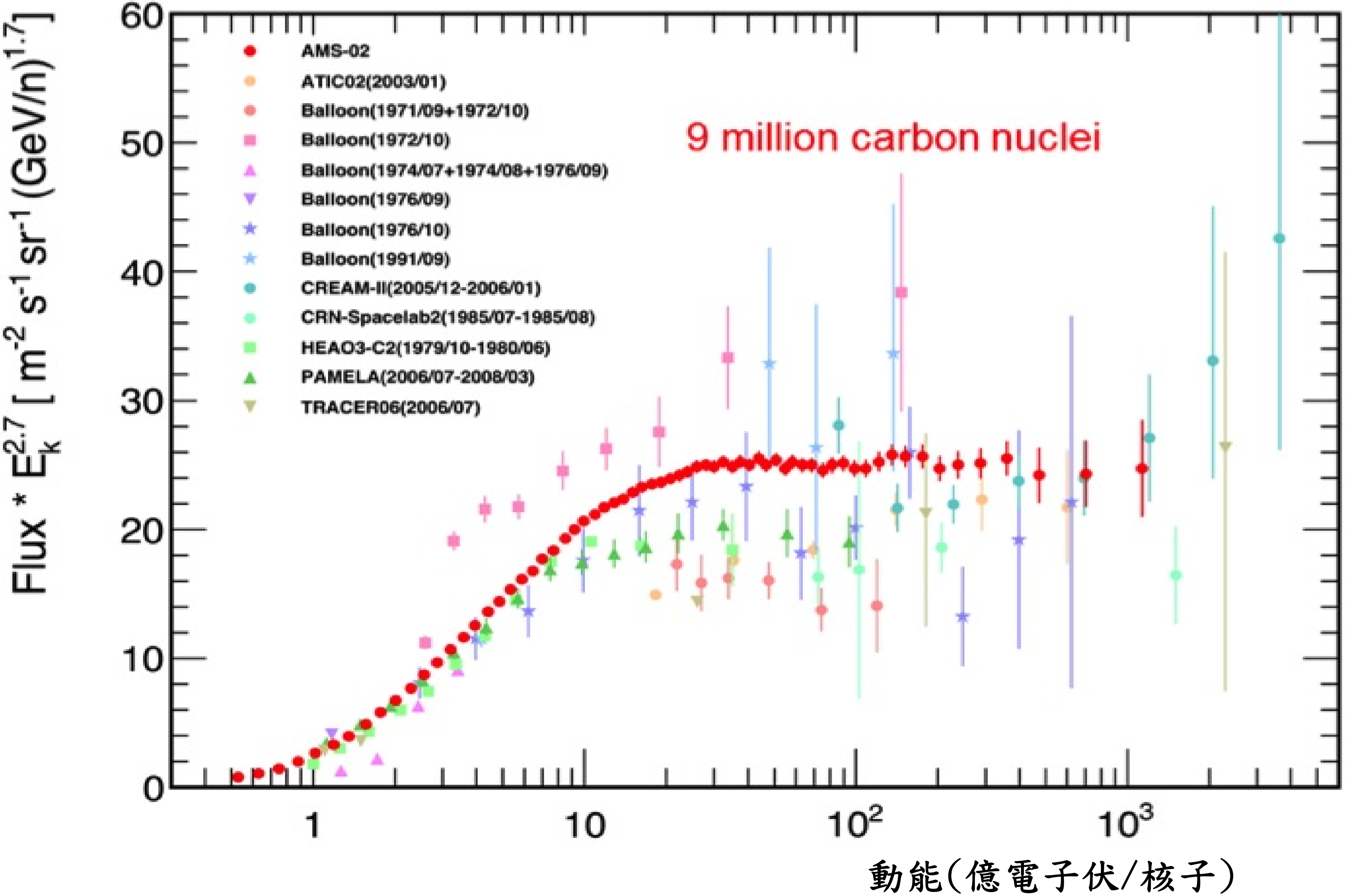
AMS Measurement of Periodic Table



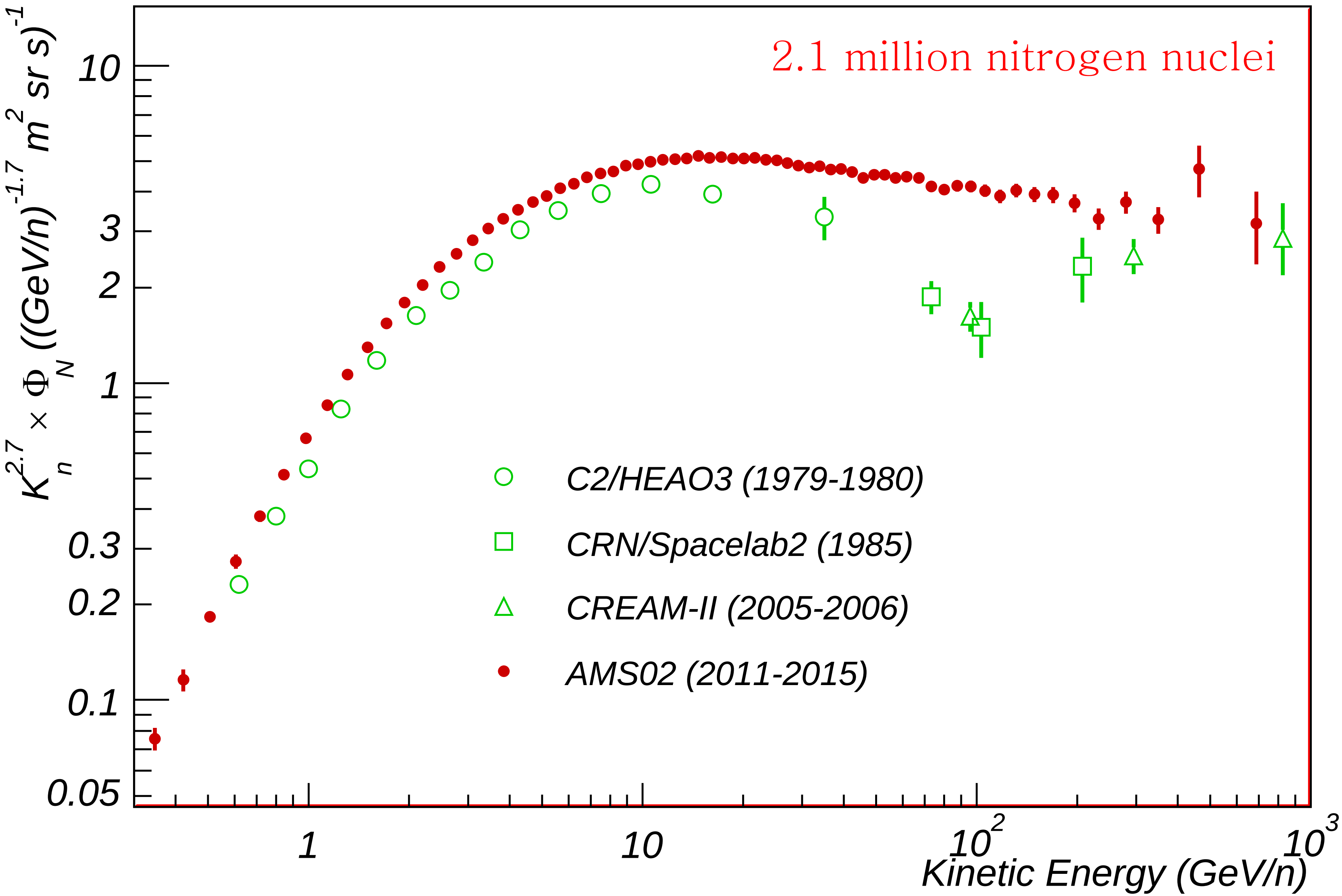
Lithium flux from AMS



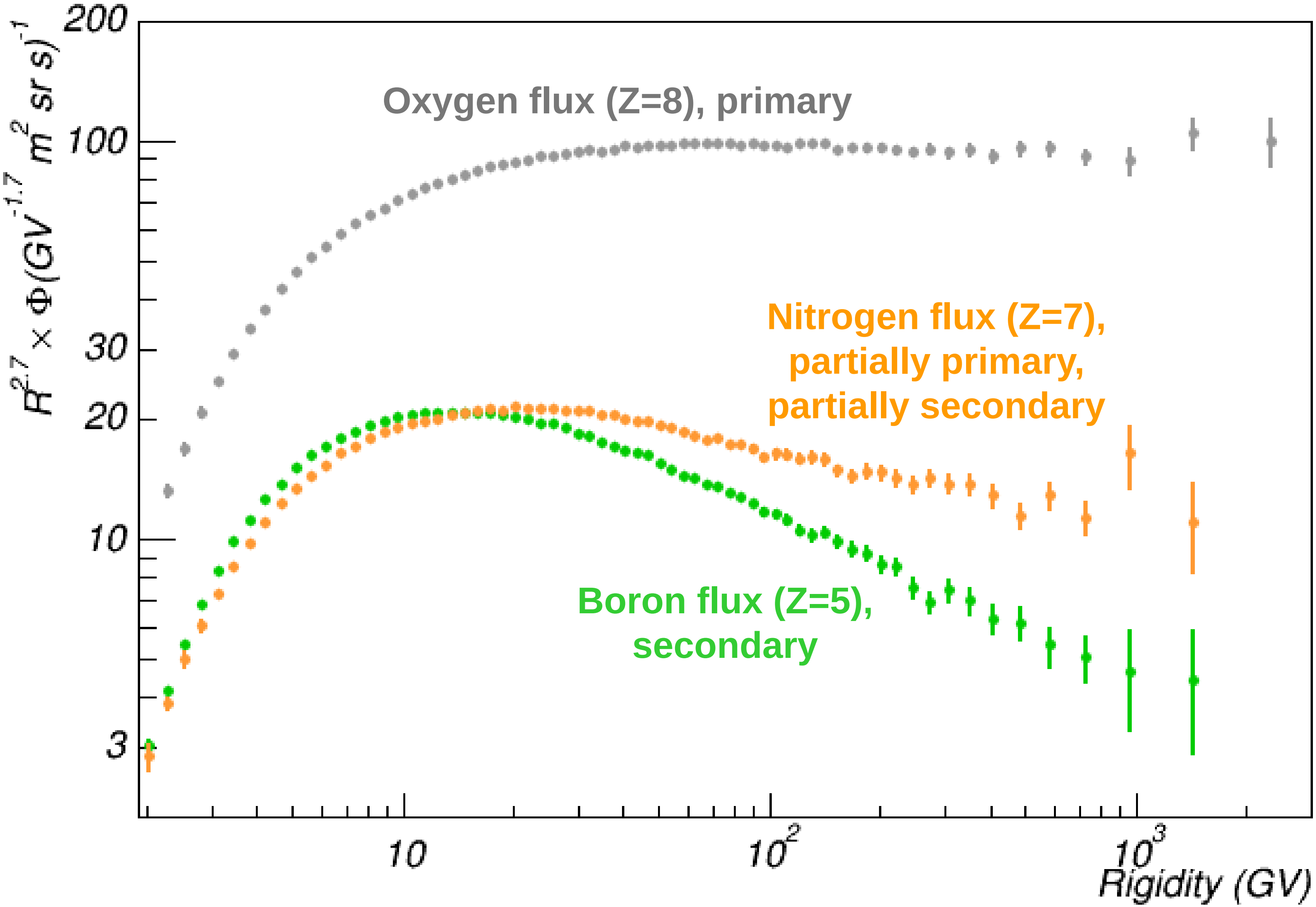
Carbon Flux from AMS



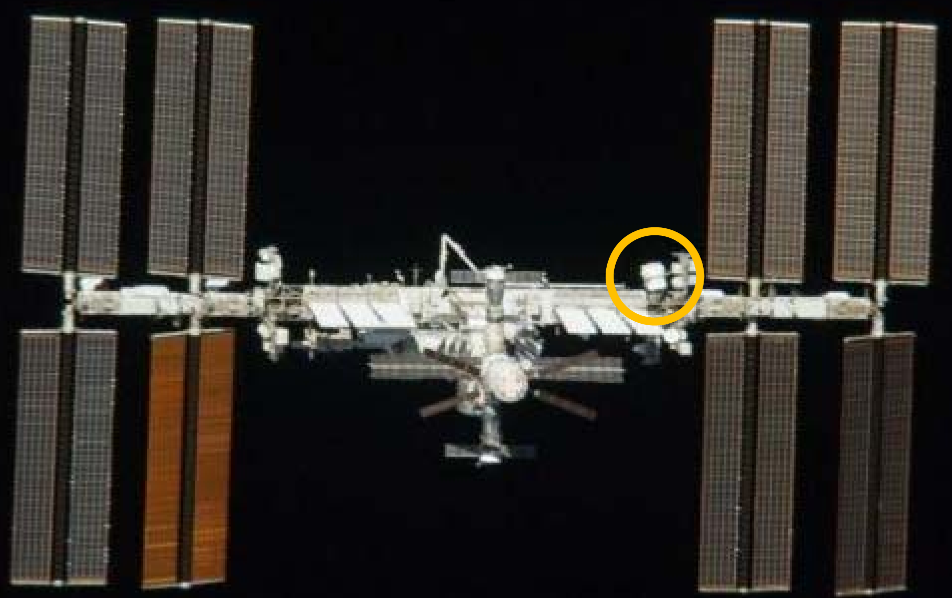
Nitrogen Flux from AMS



Fluxes of Light Nuclei: primaries & secondaries



The latest AMS measurements of the positron fraction, the behavior of the fluxes of electrons, positrons, protons, helium, and other nuclei is providing new, precise, and unexpected information.



AMS physics for the lifetime of the Space Station

Accurate measurement (~1%) of Cosmic Rays to higher energies including:

a. Complete the study of Dark Matter

b. Search for the Existence of Antimatter

c. Search for New Phenomena, …

In the past century, measurements of charged cosmic rays have typically contained ~30-50% accuracy.

AMS is providing cosmic ray information with ~1% accuracy.

This improvement in accuracy provides new insights.