# Recent results from the AMS-02 experiment



### Manuela Vecchi

Rosalind Franklin Fellow - University of Groningen



# THE ALPHA MAGNETIC SPECTROMETER

A particle physics detector operating on the International Space Station

Separates hadrons from leptons, matter from anti-matter and able to do CRs chemical and isotopic composition in GeV to TeV range.





## AMS-02 On Orbit

From May 19<sup>th</sup> 2011 active on ISS, operating continuously since then. AMS has collected >80 billion cosmic rays in 5 years. With such a statistics the most rare components of the cosmic rays are visible. To match the statistics, systematic errors studies have become important.

AMS is expected to take data for all the ISS lifetime (now projected at 2024).



### The AMS-02 Collaboration

**EWHA** 

**TAIWAN** 

**CSIST (Taipei)** 

NCU (Chung Li)

NCKU (Tainan)

# GALACTIC CR COMPOSITION

We can perform direct measurements of CRs below the knee, before they interact with the atmosphere.



# COSMIC RAYS IN THE GALAXY



#### Primary cosmic rays:

- Produced directly in the source
- Known sources (E< 10<sup>16</sup> eV): SNRs
- Primary cosmic rays include e-, p, He, C, …

#### Secondary cosmic rays:

- Produced in the interaction of primaries in the interstellar medium
- Secondary cosmic rays include e<sup>-</sup>, e<sup>+</sup>, anti-p, B, ...

$$\begin{array}{c} p + p_{\text{ism}} \to \pi^{+} + \dots \\ & \downarrow \mu^{+} + \nu_{\mu} \\ & \downarrow e^{+} + \nu_{e} + \overline{\nu}_{\mu} \end{array}$$



CR transport

Li, Be, B, N isotopes

CR sources

e-, p, He, C, N, O

e+, p-bar

CR transport

Li, Be, B, N isotopes

CR sources

e-, p, He, C, N, O

e+, p-bar

Solar Physics

e-, p, He, C, N, O isotopes

CR transport

Li, Be, B, N isotopes

CR sources

e-, p, He, C, N, O

e+, p-bar

Solar Physics

e-, p, He, C, N, O isotopes

D-bar, anti-nuclei

Primordial Antimatter & DM

### ENERGY MEASUREMENT



### MOMENTUM MEASUREMENT



# **Multiple Measurements of Charge**



### FLUX MEASUREMENT



## AMS-02 PROTON AND HELIUM RESULT



- Based on 50 million events (2011-2013)
- The helium flux cannot be described by a single power law.
- A transition in the spectral index occurs around 200 GV.

Based on 300 million events (2011-2013) The proton flux cannot be described by a single power law. A transition in the spectral index occurs around 200 GV.



### **RIGIDITY DEPENDENCE OF NUCLEI**



He, C, O: They all deviate from a single power law above 200 GV and harden in an identical way.
Li, Be,B: They all deviate from a single power law above 200 GV and harden more than primaries.
N: The rigidity dependence is distinctly different from the primary and the secondary fluxes.

### **RIGIDITY DEPENDENCE OF NUCLEI**



He, C, O: They all deviate from a single power law above 200 GV and harden in an identical way.
Li, Be,B: They all deviate from a single power law above 200 GV and harden more than primaries.
N: The rigidity dependence is distinctly different from the primary and the secondary fluxes.

### **RIGIDITY DEPENDENCE OF NUCLEI**



He, C, O: They all deviate from a single power law above 200 GV and harden in an identical way.
Li, Be,B: They all deviate from a single power law above 200 GV and harden more than primaries.
N: The rigidity dependence is distinctly different from the primary and the secondary fluxes.

### HOW TO INTERPRET THE SPECTRAL TRANSITION?

- Spectral hardening at high energy. Plausible explanations include:
  - Hardening of the injected spectrum from the source

[Biermann et al. 2010, Ohira et al. 2011, Yuan et al. 2011, and Ptuskin et al. 2013, Thoudam & Horandel 2013....]

- $\rightarrow$  Same hardening expected for secondaries and primaries
- $\rightarrow$  No hardening of the Sec./Prim. ratio

#### - Changes in the propagation properties in the Galaxy

[Ave et al. 2009, Tomassetti 2012, and Blasi et al. 2012,...]

- → Stronger hardening expected for Secondaries
- $\rightarrow$  Hardening of the Sec./Prim. Ratio

# CR ANTIMATTER MEASUREMENTS

- Main background: protons  $(S/B \sim 10^{-4})$
- Background is reduced combining complementary detection techniques



### LEPTON/HADRON SEPARATION

ISS Data: 73-140 GeV, Z=1



## **RIGIDITY DEPENDENCE OF "LIGHT" CRS**

PRL 117, 091103 (2016)



### SUMMARY PLOT OF AMS-02 MEASUREMENTS



# SUMMARY

- AMS-02 is taking data since May 2011 and it brought the CR physics to a new precision level in the GeV to TeV energy region.
- > AMS-02 data brought to light a lot of unexpected features below the knee, related to new physics phenomena.
- AMS-02 has a unique access to the antimatter component of CRs, related to dark matter and matter-antimatter asymmetry.
- It is time to put all the results into a unique coherent model for CRs below the knee.
- Stay tuned for light antinuclei ....

