Solar modulation with AMS

Veronica Bindi, AMS Collaboration

Physics and Astronomy Department
University of Hawaii at Manoa
Honolulu, Hawaii, US

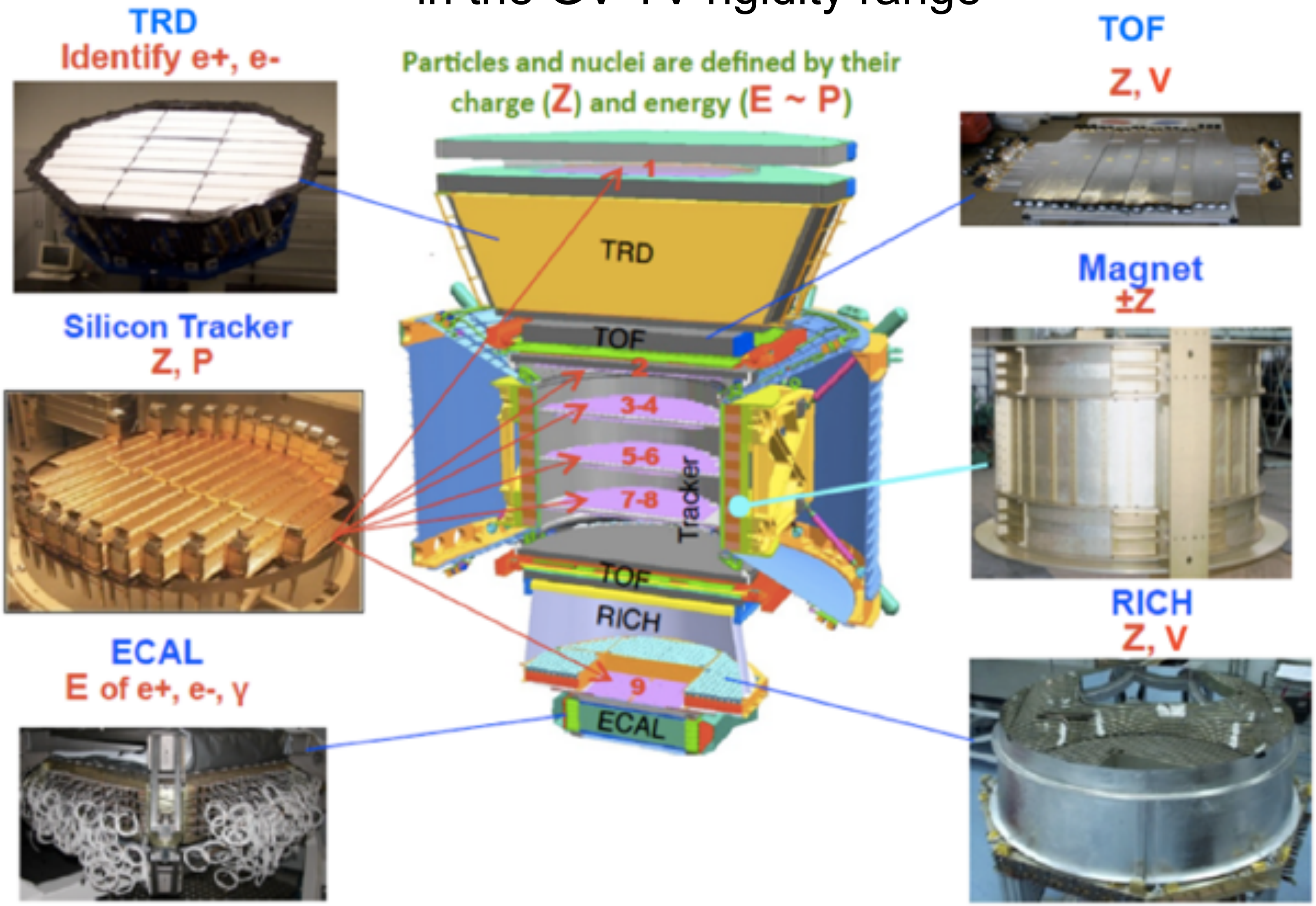
ICRC2017
35th International Cosmic Ray Conference
The Astroparticle Physics Conference
12-20 JULY, 2017
BEXCO, BUSAN, KOREA

AMS on the ISS

May 19, 2011 and for the duration of the ISS.

Particle Identification with AMS

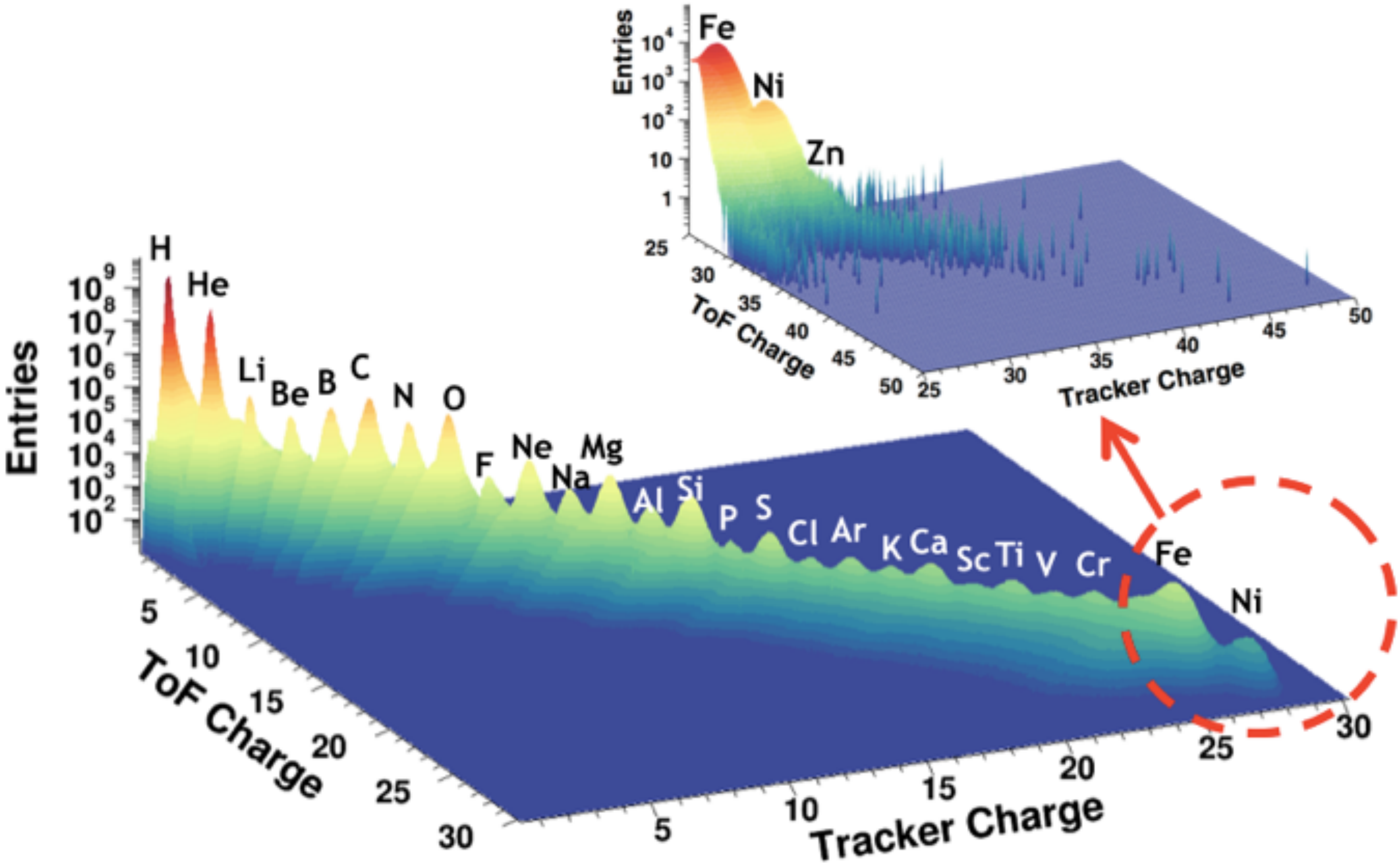
AMS is a general purpose detector which measures particles in the GV-TV rigidity range



More details TeVPA 2017 talk: M. Heil

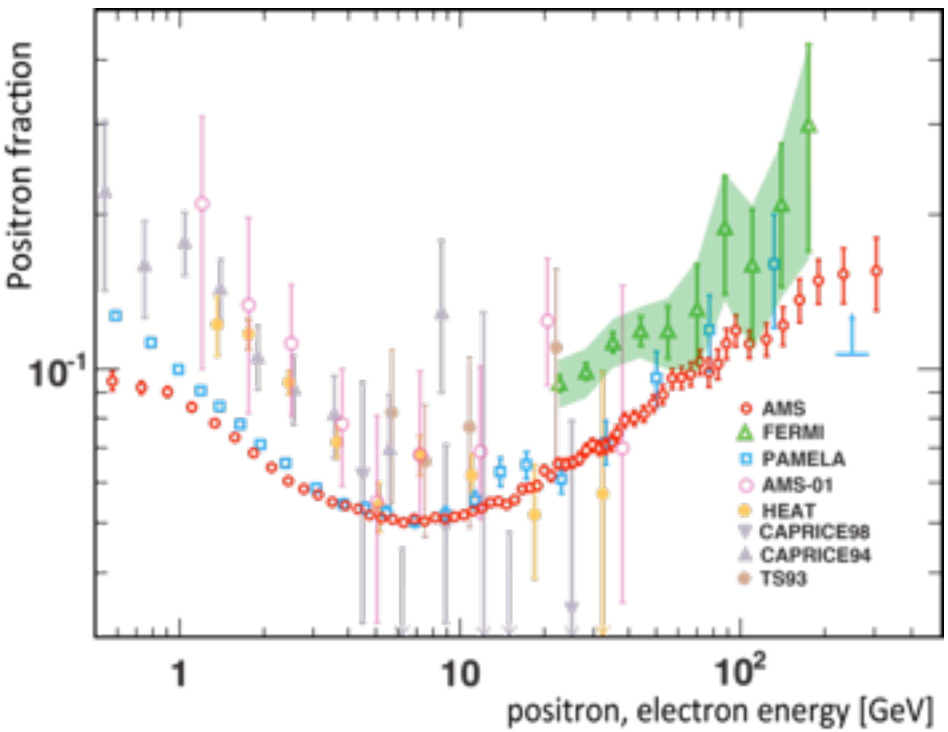
Particle identification with AMS

In 6 years of operation, AMS has measured over 100 billion events.



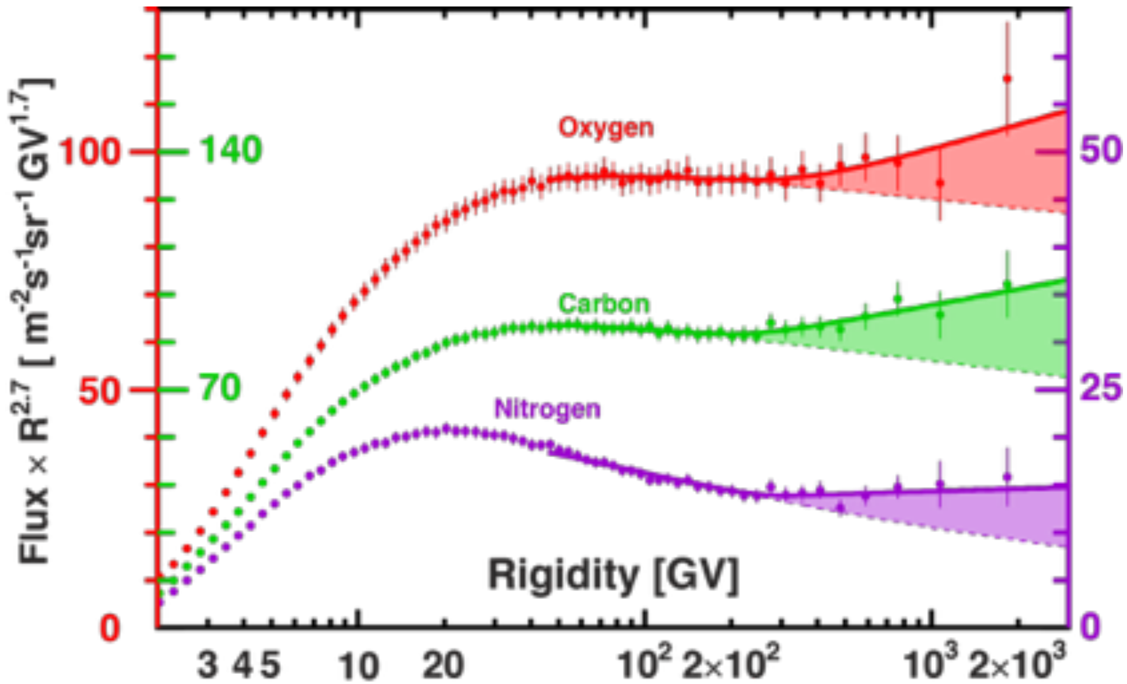
AMS Scientific Goals

Indirect Dark Matter search



M. Aguilar (AMS collaboration) PRL110,141102 (2013)

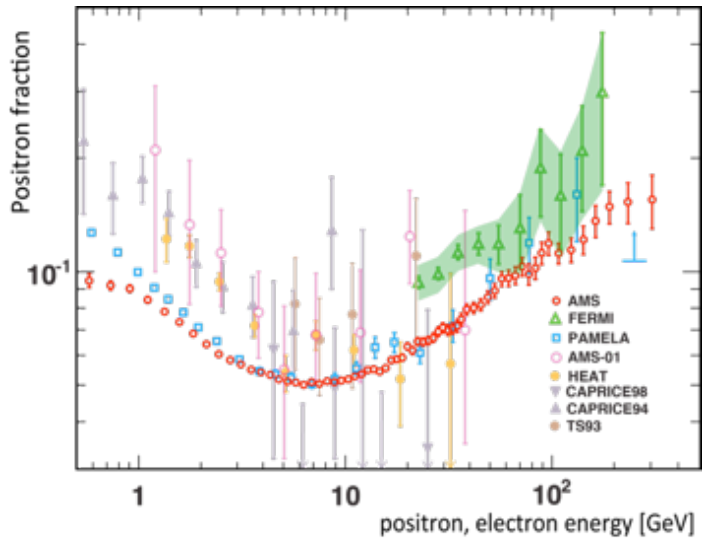
Galactic Cosmic Rays study

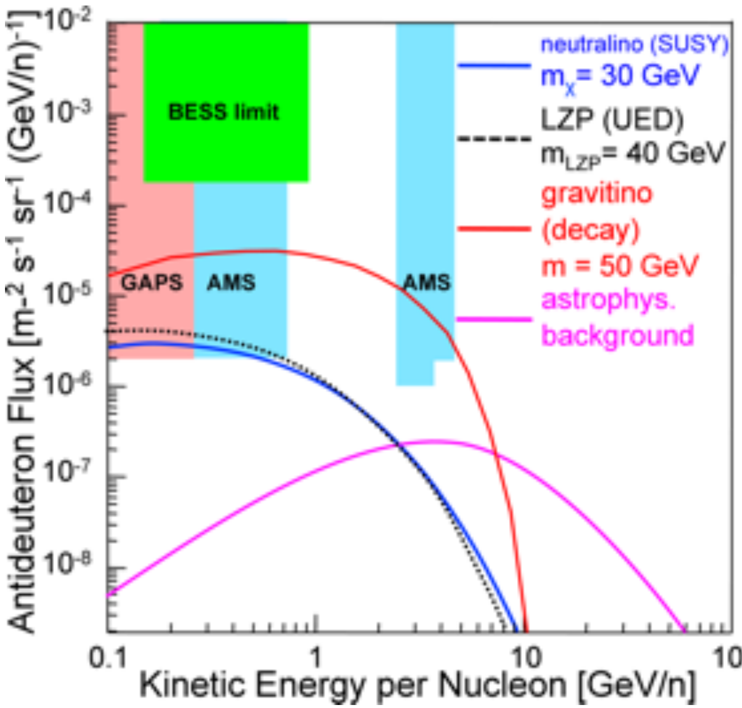


Interesting features have been measured at high energies and more has to come in the near future.

New Goal: Study of the time variation of the low energy part of the spectrum.

Solar modulation: Dark Matter search





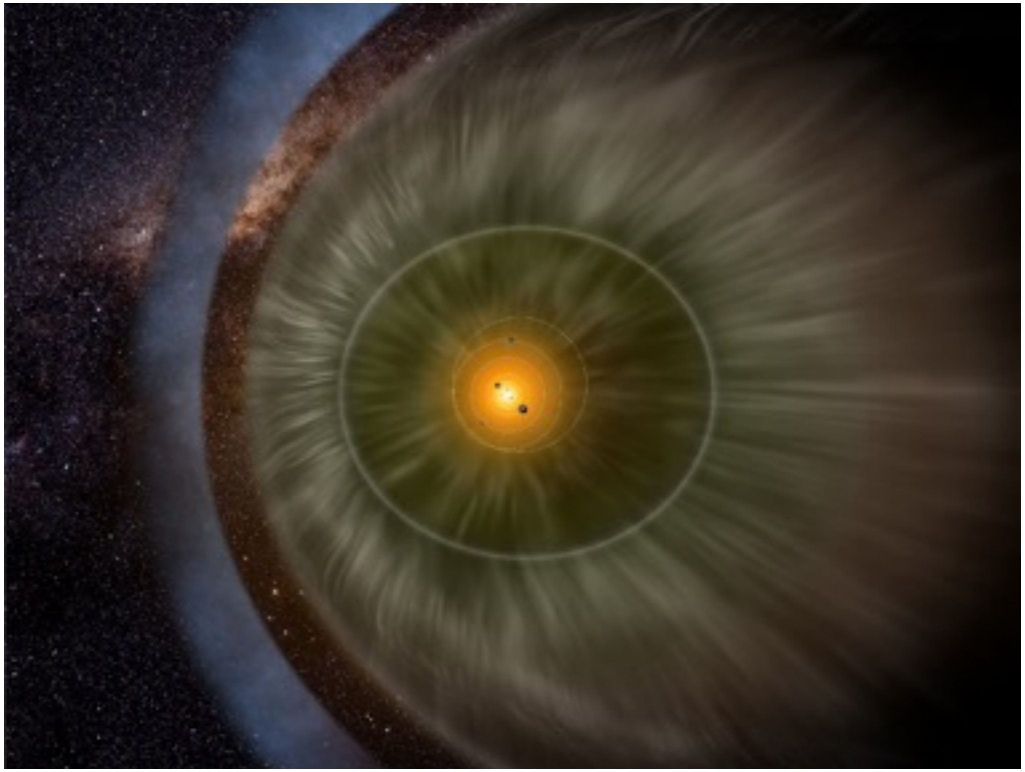
Uncertainties at low energies due to the effects of Solar modulation, increase the errors on theoretical models used for Dark Matter interpretation of the excess in the antimatter channels and in evaluation of the secondary background.

Charge sign effects affect the DM signatures expected at low energies (anti-protons, anti-deuteron).

Solar Modulation: GCR in heliosphere

Precise measurements of the time-dependent GCRs spectra are important:

- to understand the propagation of GCRs in the heliosphere.
- to test theories of particles diffusion (charge and mass) and drift (charge-sign).
- to study the effect on cosmic rays due to the reversal in the solar polarity.



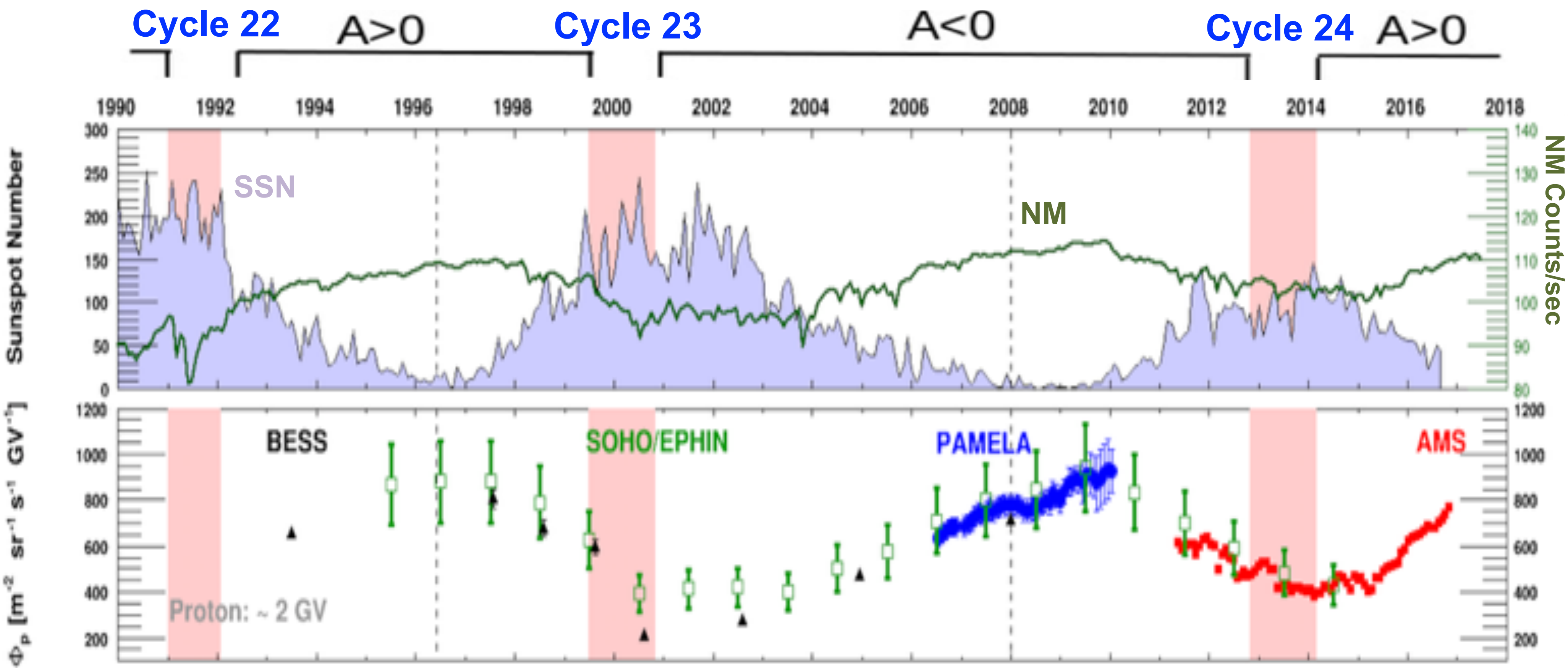
$$\frac{\partial f}{\partial t} = \nabla \cdot [K \cdot \nabla f] - V \cdot \nabla f - \langle \nu_D \rangle \cdot \nabla f + \frac{1}{3}(\nabla \cdot V)\frac{\partial f}{\partial \ln p} + Q(r, p, t)$$

CR phase space density, averaged over momentum directions | **Diffusion** | **Convection SW** | **Particle Drift** | **Adiabatic energy losses** | **Local sources**

Parker transport equation (1965)

Solar activity measured by AMS

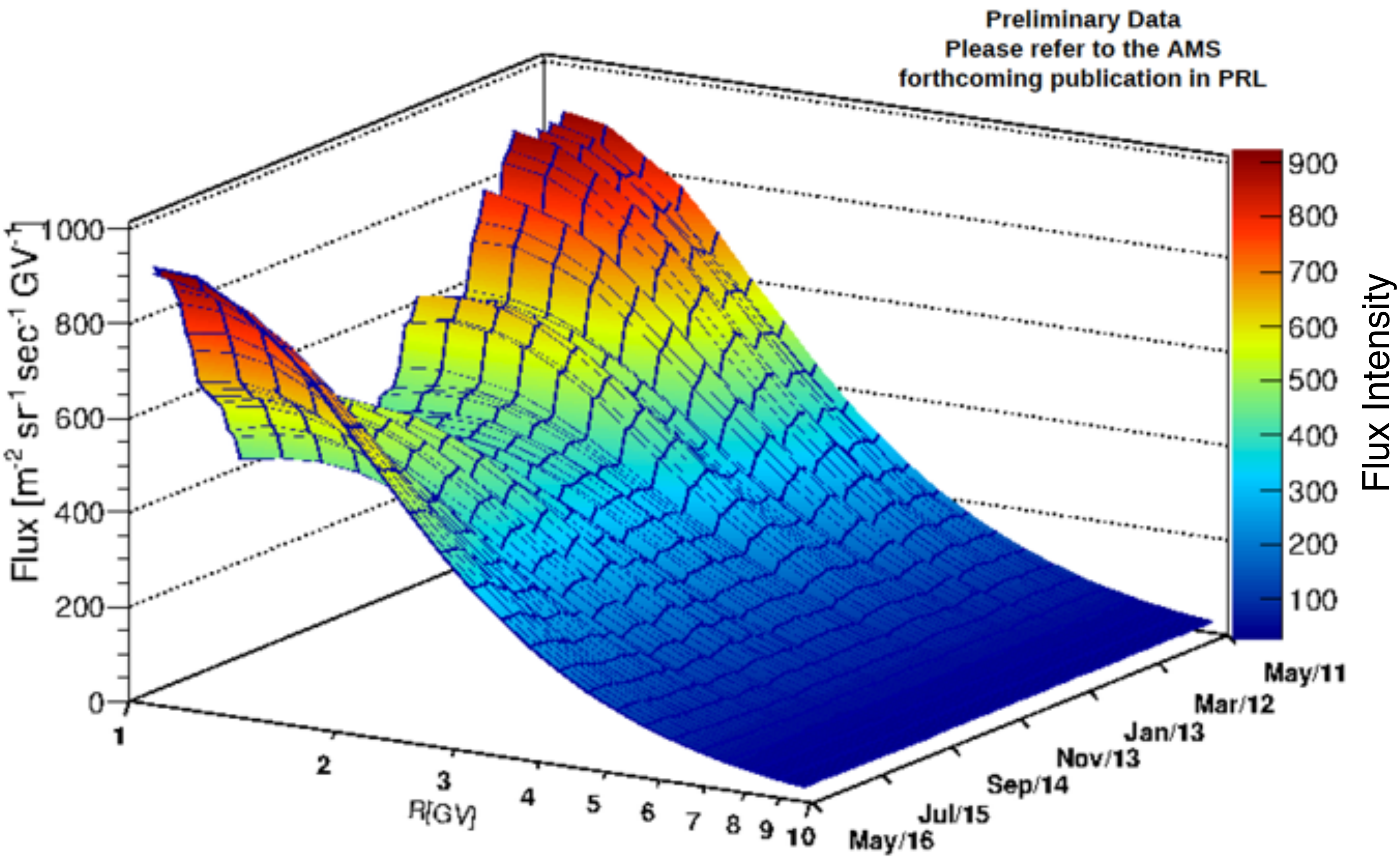
The Sun goes through an 11-year activity cycle shown by sunspots number. At each solar maximum the Sun flips its magnetic field polarity (A>0, A<0) showing a periodicity of 22 years.



The flux of galactic cosmic rays is anti-correlated with the intensity of the solar activity.

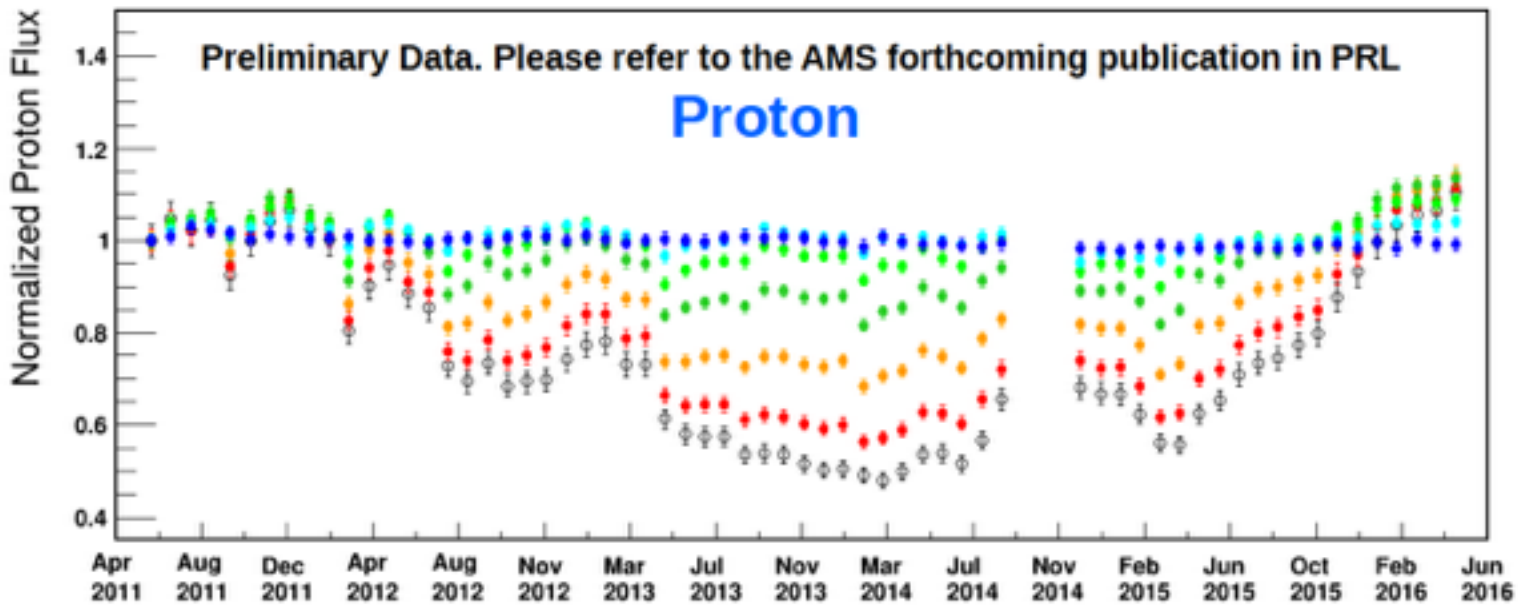
Daily sunspot number: http://www.sidc.be/silso/datafiles

AMS Monthly Proton Flux five years of data



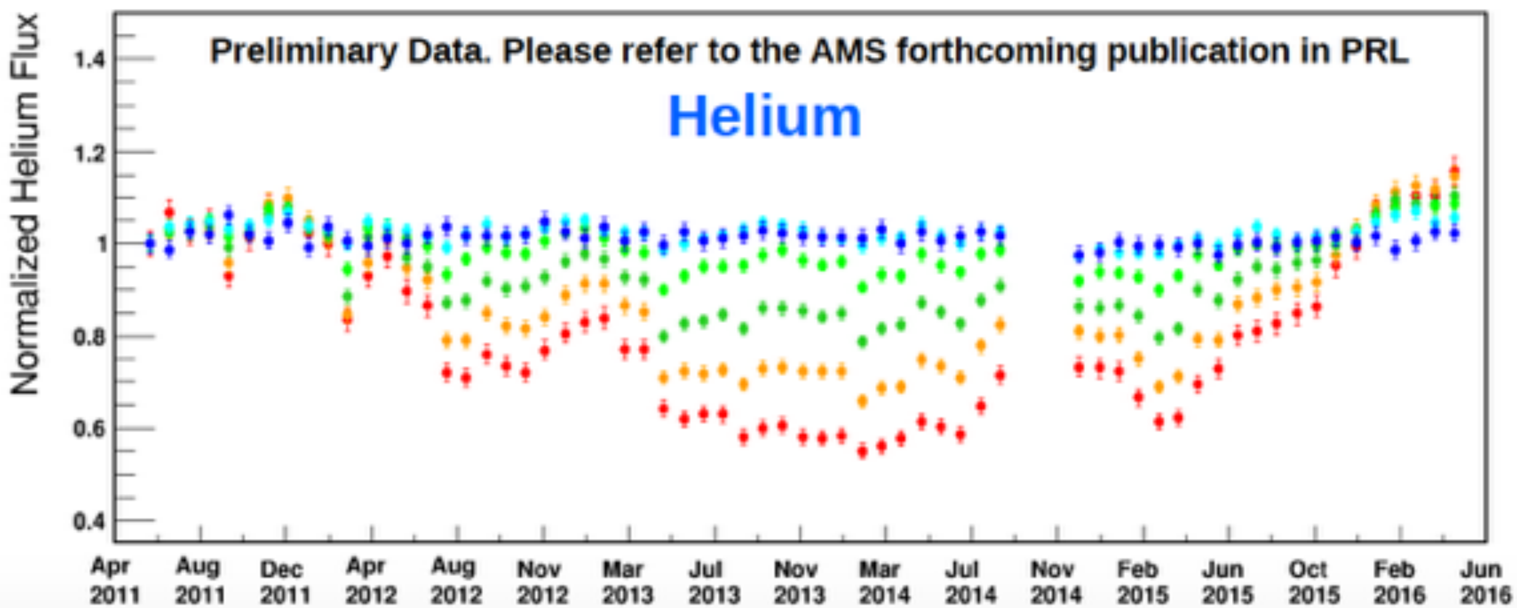
Monthly Proton & Helium Fluxes

Minimum of the flux around Feb 2014 for most of rigidities



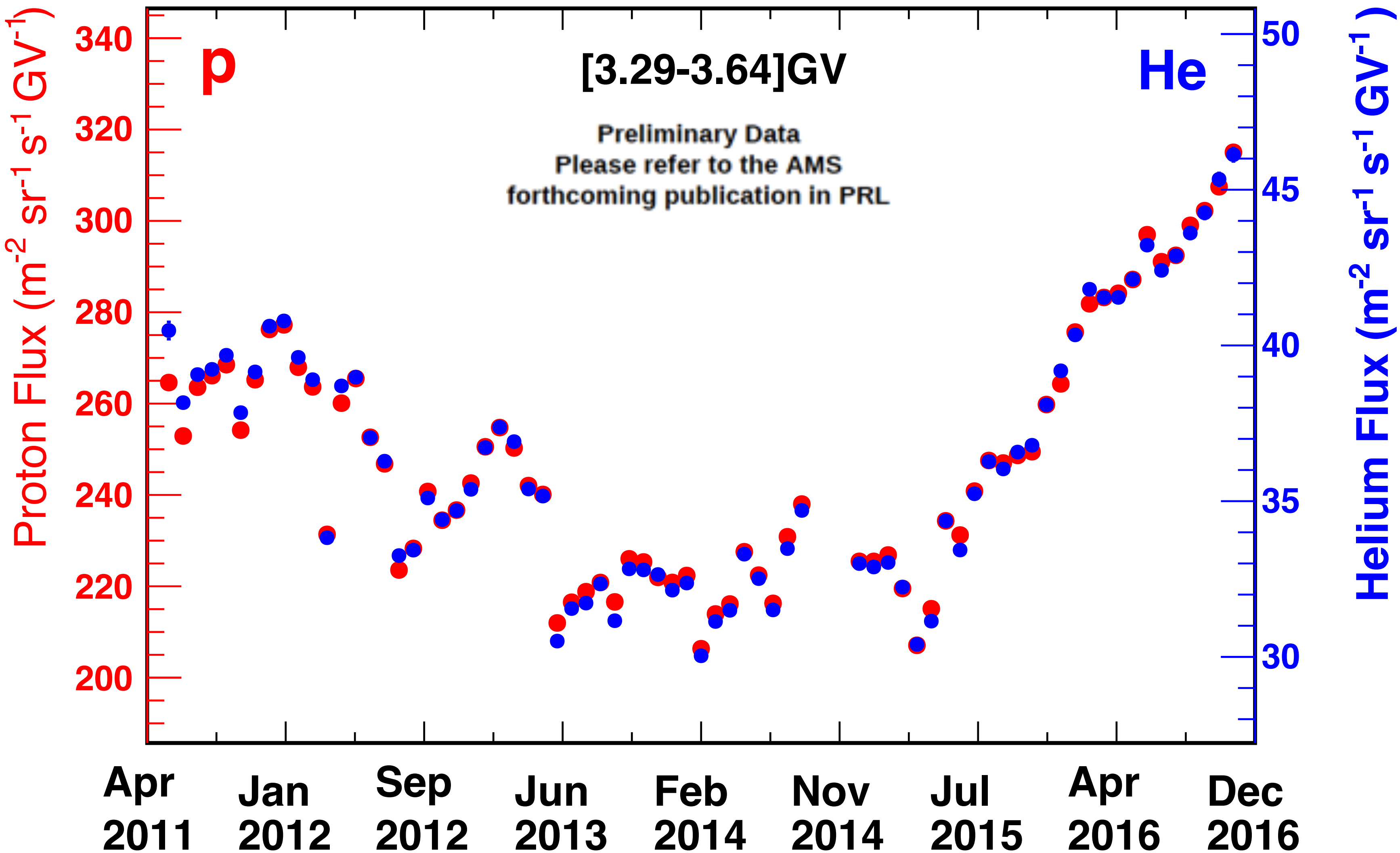
Monthly fluxes

41.90-45.10 GV
10.10-11.00 GV
5.37-5.90 GV
3.29-3.64 GV
2.15-2.40 GV
1.51-1.71 GV
1.16-1.33 GV



41.90-45.10 GV
10.10-11.00 GV
5.37-5.90 GV
3.29-3.64 GV
2.15-2.40 GV
1.51-1.71 GV

Monthly Proton & Helium Fluxes



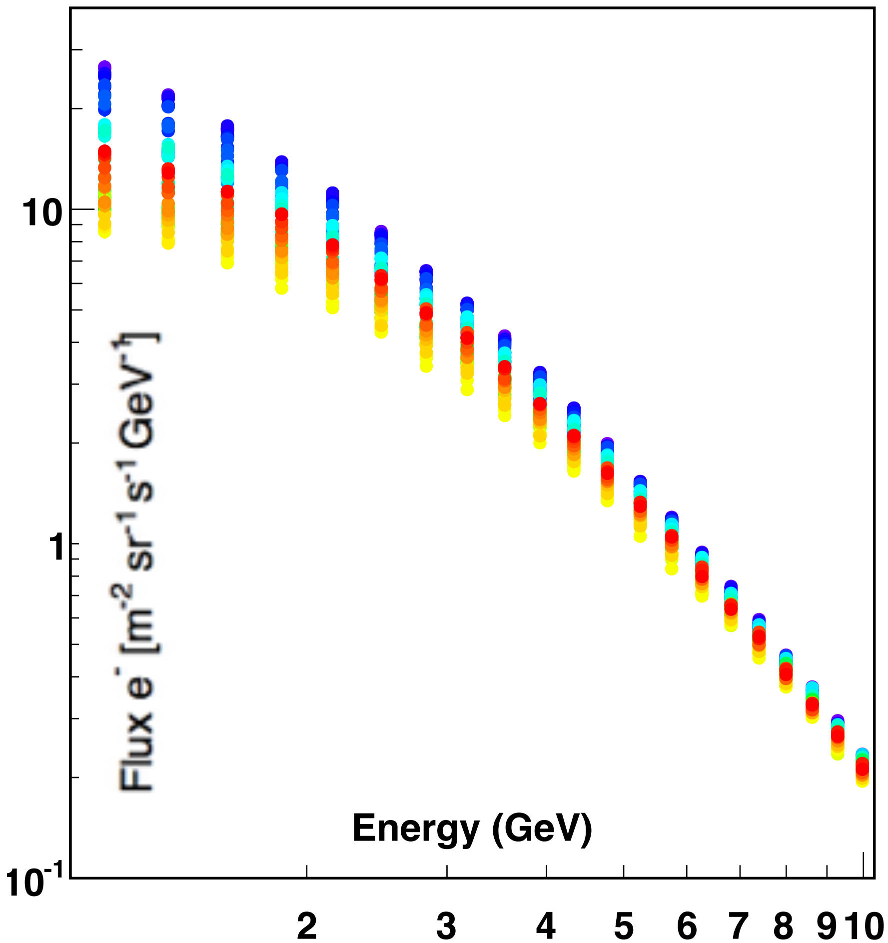
AMS will study how solar modulation affects all different cosmic ray species.

Electron & Positron Fluxes

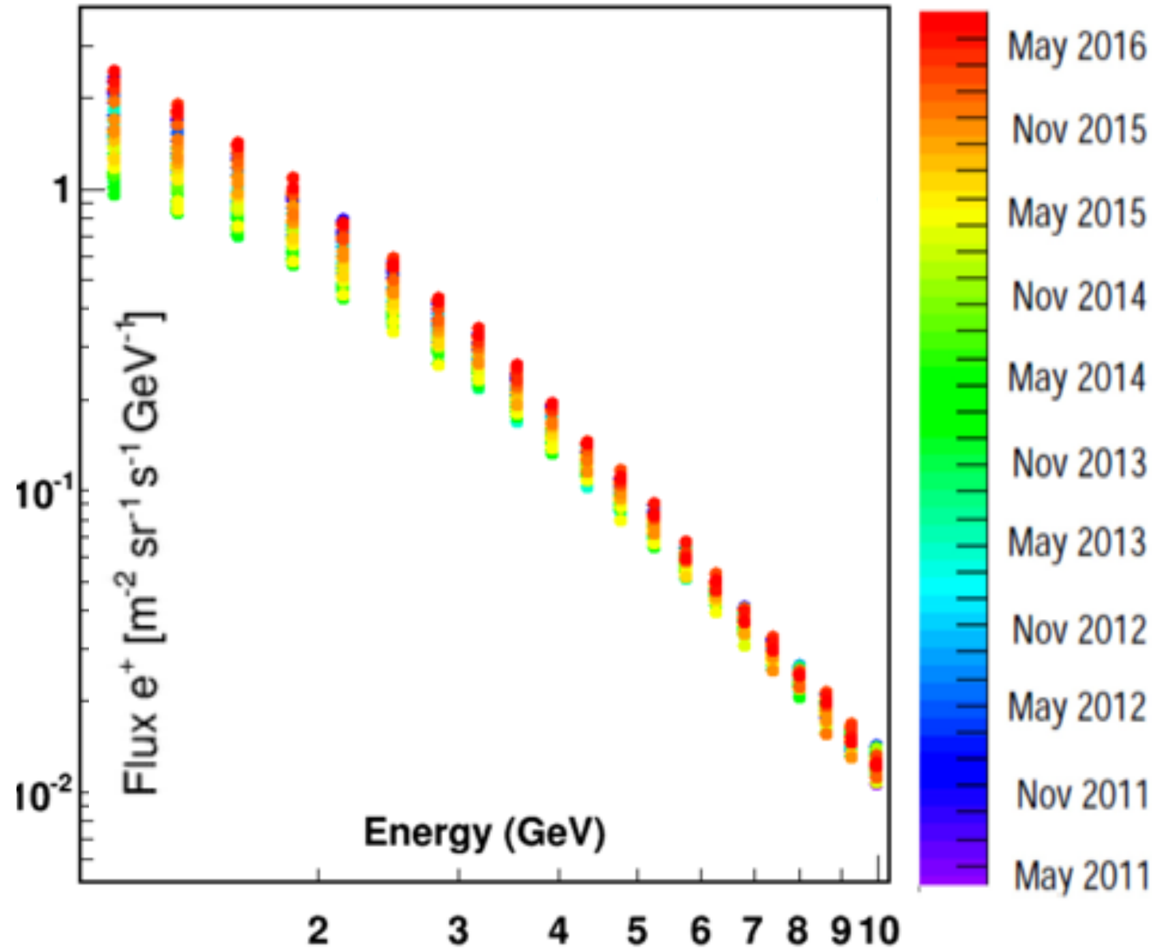
Each color represents a 27 days integration flux.

Preliminary Data
Please refer to the AMS forthcoming publication in PRL

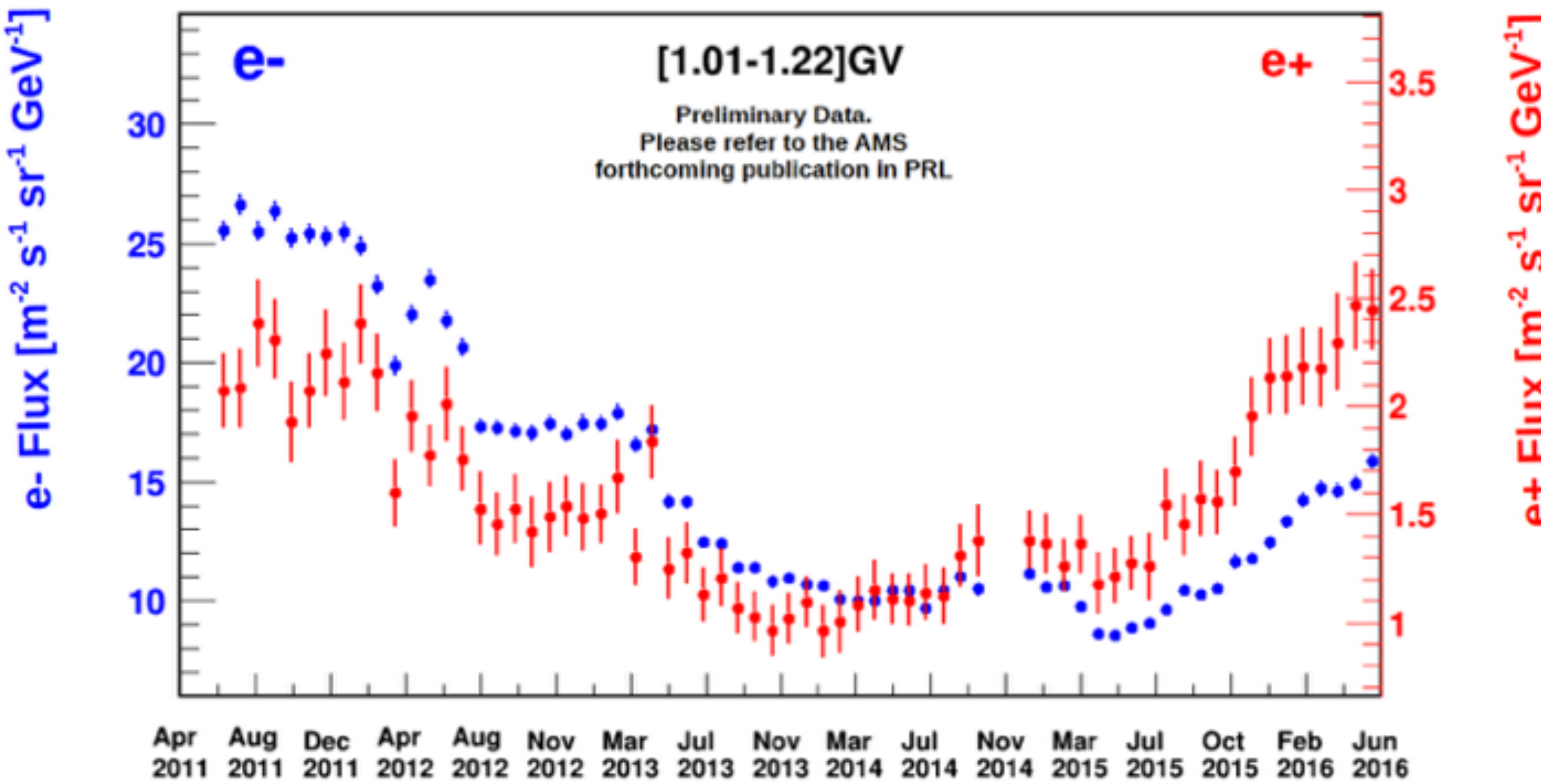
Electrons



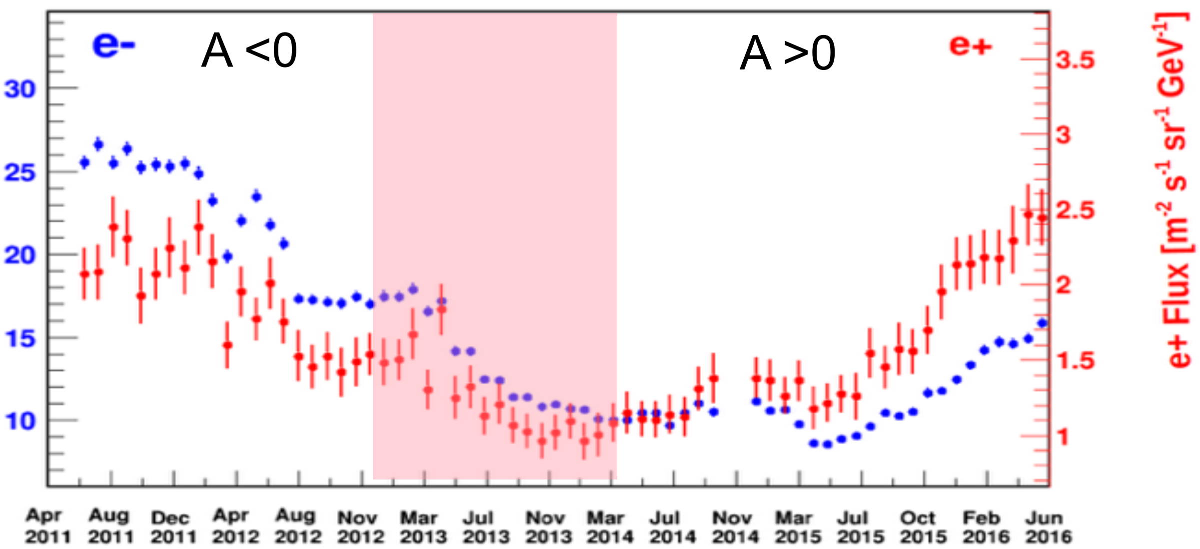
Positrons

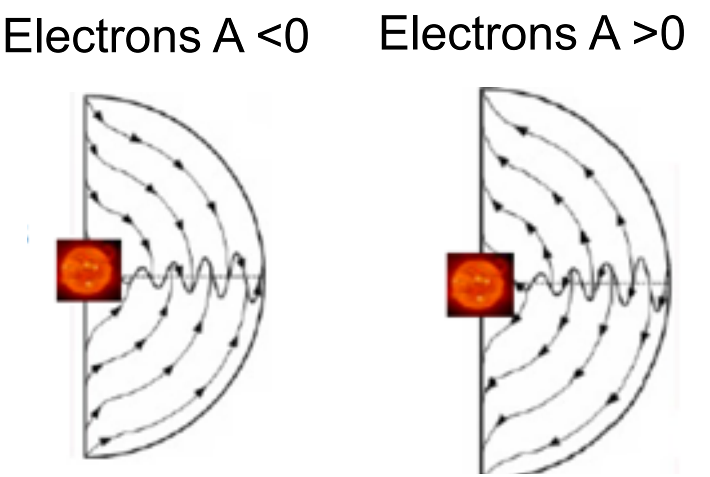


Monthly e+ and e- flux
Time profile

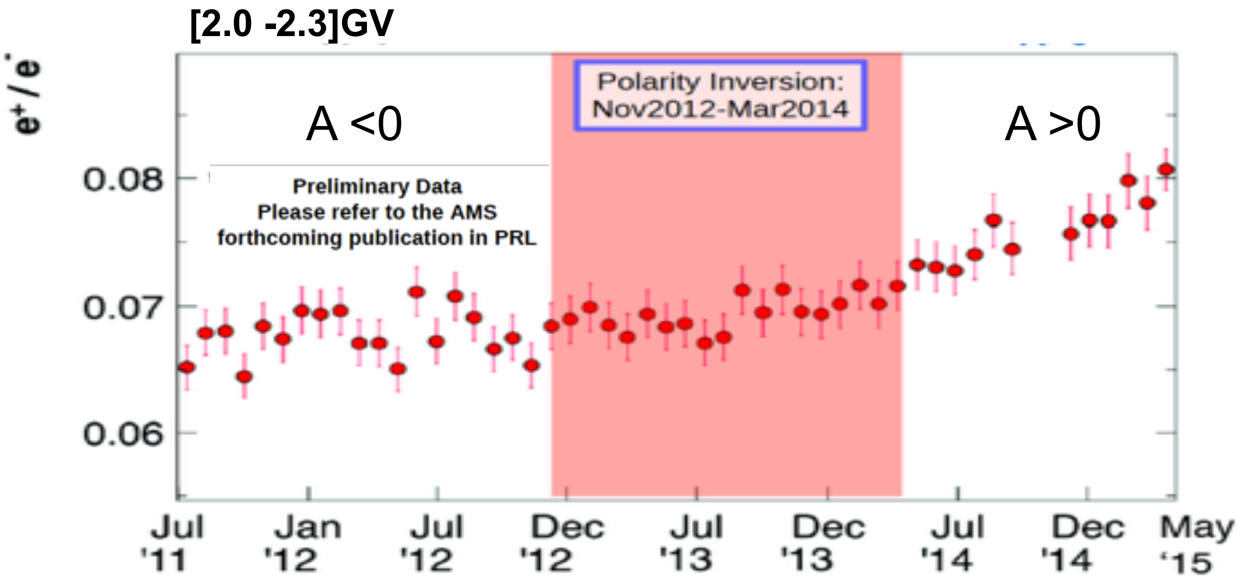


Change of Solar Polarity and Particle Drift





AMS e+/e- ratio clearly shows the charge-sign dependence of solar modulation.



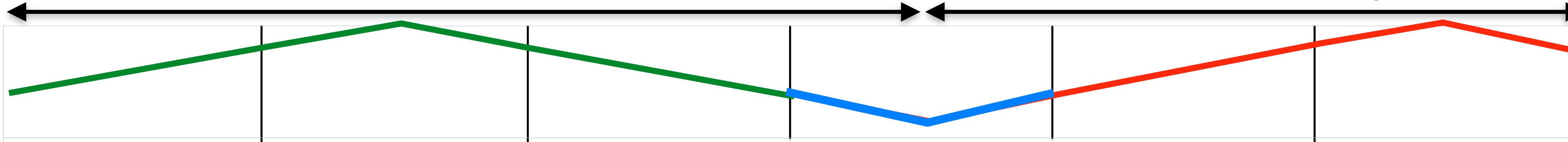
Repeat the study with pbar/p.

AMS will measure the drift of positive vs negative particles during a solar minimum with positive polarity A>0.

Polarity inversion period from: X. Sun et al., Astroph. J., 798, 114 (2015)

AMS data taking till 2024 - Agenda

Cycle 24 | Cycle 25



Years: 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024

Polarity: A<0	Reversal	A>0	A>0	A>0	Reversal
ascending phase	solar maximum	descending phase	solar minimum	ascending phase	solar maximum

DRIFT :
e-, e+ , p, pbar

Comparing data collected before, during and after the solar maximum AMS can study in details the effects due to the solar polarity reversal.

AMS will measure the drift of positive vs negative particles during the solar minimum with positive polarity A>0.

AMS will compare solar maximum of cycles 25 (A>0) and 24 (A<0) and the solar polarity reversal.

DIFFUSION :
All species of GCR

AMS is measuring the modulation of different nuclei during a solar cycle.

FD and SEP :

Measured 27 SEPs and identified so far 33 FDs.

Not expected major events during minimum

Lots of new SEPs and FDs.

Summary & Conclusions

A new era in galactic cosmic rays understanding has started, not only at high energy, but also at low energy in the region affected by the solar modulation thanks to the precise and continuous observations from space by PAMELA in solar cycle 23 and now AMS-02 in solar cycle 24 and 25.

New and precise measurements are increasing our knowledge of important effects such as diffusion and drift in the heliosphere, allowing the detailed study of propagation.

These measurements will serve as a high-precision baseline for continued studies of GCR solar modulation, SEPs, space radiation hazards, magnetospheric effects, trapped particles and in many other fields.

Near future forthcoming AMS publications on solar modulation: time evolution of proton and helium fluxes, electron and positron fluxes, and antiproton/proton ratio.